BNL- 52568

Proceedings of RIKEN BNL Research Center Workshop Volume 21

RBRC SCIENTIFIC REVIEW COMMITTEE MEETING

May 27–28, 1999

Organizers

T.D. Lee and N.P. Samios

RIKEN BNL Research Center

Building 510, Brookhaven National Laboratory, Upton, NY 11973, USA

Other RIKEN BNL Research Center Proceedings Volumes:

Volume 20 - Gauge-Invariant Variables in Gauge Theories - BNL-

Volume 19 - Numerical Algorithms at Non-Zero Chemical Potential - BNL-

Volume 18 - Event Generator for RHIC Spin Physics - BNL-

Volume 17 - Hard Parton Physics in High-Energy Nuclear Collisions - BNL-

Volume 16 - RIKEN Winter School — Structure of Hadrons —Introduction to QCD Hard Processes— BNL-

Volume 15 - QCD Phase Transitions - BNL-52561

Volume 14 - Quantum Fields In and Out of Equilibrium - BNL-52560

Volume 13 - Physics of the 1 Teraflop RIKEN-BNL-Columbia QCD Project First Anniversary Celebration - BNL-66299

Volume 12 - Quarkonium Production in Relativistic Nuclear Collisions - BNL-52559

Volume 11 - Event Generator for RHIC Spin Physics - BNL-66116

Volume 10 - Physics of Polarimetry at RHIC - BNL-65926

Volume 9 - High Density Matter in AGS, SPS and RHIC Collisions - BNL-65762

Volume 8 - Fermion Frontiers in Vector Lattice Gauge Theories - BNL-65634

Volume 7 - RHIC Spin Physics - BNL-65615

Volume 6 - Quarks and Gluons in the Nucleon - BNL-65234

Volume 5 - Color Superconductivity, Instantons and Parity (Non?)-Conservation at High Baryon Density - BNL-65105

Volume 4 - Inauguration Ceremony, September 22 and Non-Equilibrium Many Body Dynamics - BNL- 64912

Volume 3 - Hadron Spin-Flip at RHIC Energies - BNL-64724

Volume 2 - Perturbative QCD as a Probe of Hadron Structure - BNL-64723

Volume 1 - Open Standards for Cascade Models for RHIC - BNL-64722

Preface to the Series

The RIKEN BNL Research Center (RBRC) was established in April 1997 at Brookhaven National Laboratory. It is funded by the "Rikagaku Kenkysho" (Institute of Physical and Chemical Research) of Japan. The Center is dedicated to the study of strong interactions, including hard QCD/spin physics, lattice QCD and RHIC physics through nurturing of a new generation of young physicists.

During the first year, the Center had only a Theory Group. At present, the Theory Group consists of nine Postdocs and Fellows and has an active Visiting Scientist program. In addition, the Center organizes workshops centered on specific problems in strong interactions.

Now, at RBRC's Scientific Review Committee Meeting we have an active Experimental Group with several scientific collaborators, one Postdoc and one Fellow. The construction of a 0.6 teraflop parallel processor, which was begun at the Center on February 19, 1998, was completed on August 28, 1998. In addition, a new Tenure Track Strong Interaction Theory RHIC Physics Fellow Program is under way. To this date nine institutions have joined this initiative. The Center had has held twenty workshops thus far.

Each workshop speaker is encouraged to select a few of the most important transparencies from his or her presentation, accompanied by a page of explanation. This material is collected at the end of the workshop by the organizer to form proceedings, which can therefore be available within a short time.

T. D. Lee
May 28, 1999

CONTENTS

Experimental Presentations

RBRC Scientific Review Committee Meeting

May 27-28, 1999
Brookhaven National Laboratory, Upton, NY 11973

The second evaluation of the RIKEN BNL Research Center (RBRC) took place on May 27 and 28, 1999, at Brookhaven National Laboratory. The members of the Scientific Review Committee were Professors Akira Masaike, Larry McLerran, Jack Sandweiss, Horst Stoecker, and Akira Ukawa. Professor Ukawa was unable to attend. In order to illustrate the breadth and scope of the program, each member of the Center made a presentation on his research efforts. In addition, the progress and status of the RBRC Supercomputer program was evidenced in both a tour of the facility and a presentation on its status. Although the main purpose of this review is a report to RIKEN Management (Dr. S. Kobayashi) on the health, scientific value, management and future prospects of the Center, the RBRC management felt that a compendium of the scientific presentations are of sufficient quality and interest that they warrant a wider distribution. As such we have made this compilation and present it to the community for its information and enlightenment.

Thanks to Brookhaven National Laboratory and to the U. S. Department of Energy for providing the facilities to hold this meeting.

T. D. Lee & N. P. Samios

RIKEN BNL Research Center

Bldg. 510, Brookhaven National Laboratory, Upton, NY 11973, USA

RBRC Scientific Review Committee Meeting
Brookhaven National Laboratory, Upton, NY
Physics Department, Building 510
May 27-28, 1999

Agenda

Committee Members: Akira Masaike, Larry McLerran, Jack Sandweiss, Horst Stoecker, and Akira Ukawa

<u>Thursday, May 27</u>

Orange Room

12:00 Noon	Executive Committee Working Lunch [Committee Members and T.D. Lee, N.P. Samios, M. Yanokura and H. Horie] Present Status of the RIKEN BNL Research Center	T. D. Lee/N. P. Samios

Small Seminar Room

Anthony Baltz, Chair

1:30 PM	Kaon Weak Matrix Elements with Domain Wall Quarks	Thomas Blum
1:45	The Parity Partner of the Nucleon in Quenched QCD with Domain Wall Fermions	Shoichi Sasaki
2:00	Quark Masses Using Domain Wall Fermions	Matthew Wingate
2:15	Topics in the Physics of RHIC: Parity Violation in Hot QCD, Heavy Quarks, Spin, and Nuclear Collisions	Dmitri Kharzeev
2:30	Azimuthal Asymmetries at RHIC	Daniël Boer
2:45	One-loop Calculation of 5 Gluon Amplitudes in the Background Field Gauge	Yoshiaki Yasui
3:00	Parity Violation Through Color Superconductivity	Dirk Rischke
3:15	The Chiral Phase Transition in Flavor SU(3) and Possible Signals for RHIC	Jürgen Schaffner-Bielich
3:30	Break	

-over-

Thursday, May 27
Small Seminar Room

	Gerry Bunce, Chair	
3:50	RHIC Spin Physics and the Experimental Division of the Center	Gerry Bunce
4:05	Spin Work of the Roundtable Group	Naohito Saito
4:20	Work on the Electromagnetic Calorimeter of PHENIX	Alexander Bazilevsky
4:30	RHIC Spin: Online Monitoring and Transverse Spin	Matthias Grosse Perdekamp
4:40	A New Polarimeter for RHIC	Kazuyoshi Kurita
4:50	The New Computer Center for PHENIX in Japan	Yashushi Watanabe
5:00	Concluding Comments	Masayasu Ishihara
5:15	Executive Session - *Orange Room*	
6:30 PM	Reception & Dinner - *Berkner Hall** [In conjunction with the Workshop on Gauge-Invariant Variables in Gauge Theories]	

Friday, May 28, 1999
Orange Room

8:00 AM	Executive Session (Continental Breakfast)	

Small Seminar Room

8:15 -8:45 AM	QCDSP Project	Norman Christ/ Robert Mawhinney
8:45 - 9:15	Tour of 1 Teraflop Computer	
9:15	Orange Room Reserved for Theorists	Host Liaison: Anthony Baltz
	Conference Room 2-72 Reserved for Experimentalists	Host Liaison: Gerry Bunce
12:00 Noon	Lunch - No Host - Berkner Hall, Room A Reserved Executive Session	

Orange Room

1:30 PM	Scientific Review Committee Meeting with T. D. Lee and N. P. Samios

*Please note the change of location of the reception and dinner.

Present Status of the RIKEN BNL Research Center

T. D. Lee and N. P. Samios

- September 22, 1997

  Inauguration of RBRC

- February 19, 1998

  Beginning of the 0.6 teraflops supercomputer construction

- July 15, 1998

  First RBRC Scientific Review Committee (written report)

- August 28, 1998

  Completion of the supercomputer

- October 16, 1998

  First Anniversary

- November 13, 1998

  SC 98 Gordon Bell Prize for Price Performance

RIKEN BNL Research Center
(1998 - May 1999)

- RBRC Research Scientists
- Publication List
- Seminars and Workshops
- QCD Supercomputer
- Tenure Track / RBRC RHIC Fellow
- Experimental : spin + heavy ion

RBRC RESEARCH SCIENTISTS

Fellows:	T. Blum	D. Kharzeev	D. Rischke
	M. Gross-Perdekamp (E)		
Postdocs:	A. Bazilevsky (E)	D. Boer	H. Fujii
	Y. Nara	S. Sasaki	J. Schaffner-Bielich
	M. Wingate	Y. Yasui	

Senior Scientists (mostly volunteers) and Experimental Collaborating Scientists:

A. Baltz	G. Bunce (E)	M. Gyulassy	T. Ichihara (E)
R. Jaffe	K. Kurita (E)	T. D. Lee	R. Mawhinney
S. Ohta	N. Saito (E)	N. Samios	E. Shuryak
Y. Watanabe (E)			

RIKEN *(in Japan)*

M. Ishihara
K. Yazaki

Publication List

RBRC-1 H. Fujii and H. Shin "Dilepton Production in Meson Condensed Matter", Prog. Theor. Physics <u>98</u>, 1139 (1997)

. . . .

RBRC-31 M. Wingate *et al.* "Heavy-Light Decay Constants: Conclusions from the Wilson Action," To appear in the Proceedings of Lattice '98, Hep-lat/9809109.

presented at the first Anniversary Celebration
Oct. 16, '98

 Since 10/16/98 —

32. D. Kharzeev, R. D. Pisarski, and M. Tytgat, "Parity-odd Bubbles in Hot QCD," [hep-ph/9808366]; to appear in *Proc. Continuum Advances in QCD*, Minneapolis, 1998.

33. D. Kharzeev, "Workshop on Quarkonium Production in Relativistic Nuclear Collisions: Summary," [hep-ph/9812214]; to appear in *Proc. Quarkonium Production*, Seattle, 1998.

34. T. D. Lee, "Generalization of Classical Yang-Mills Fields in Ultra-relativistic Nuclear Collisions," to appear in *Proc. 3rd Workshop on Continuous Advances in QCD*, Minneapolis, 1998.

35. S. Sasaki and O. Miyamura, "Lattice Study of $U(1)_A$ Anomaly: The Role of QCD-Monopoles," [hep-lat/9810039]; Phys. Lett. B443, 331-337 (1998).

36. N. K. Glendenning and J. Schaffner-Bielich, "Kaon Condensation and Dynamical Nucleons in Neutron Stars," Phys. Rev. Lett. 81, 4564, 1998.

37. A. J. Baltz, Alred Scharff Goldhaber, and Maurice Goldhaber, "The Solar Neutrino Puzzle: An Oscillation Solution with Maximal Neutrino Mixing," Phys. Rev. Lett. 81, 5730 (1998).

38. A. J. Baltz and L. McLerran, "Two Center Light Cone Calculation of Pair Production Induced by Ultrarelativistic Heavy Ions," Phys. Rev. C58, 1679 (1998).

39. E. Farhi, N. Graham, P. Haagensen, R. L. Jaffe, "Finite Quatum Fluctuations About Static Field Configurations," [hep-th/9802015], Phys. Lett. B427, 334-342 (1998).

40. P. Papazoglou, D. Zschiesche, S. Schramm, J. Schaffner-Bielich, H. Stocker and W. Greiner, "Nuclei in a Chiral SU(3) Model," [nucl-th/9806087], Phys. Rev. C59, 411 (1999).

41. D. Chen, P. Chen, N. Christ, R. Edwards, G. Fleming, A. Gara, S. Hansen, C. Jung, A. Kaehler, A. Kennedy, G. Kilcup, Y. Luo, C. Malureanu, R. Mawhinney, J. Parsons, C. Sui, P. Vranas, Y. Zhestkov, "Status of the QCDSP Project," [hep-lat/9810004]; to appear in *Proceedings of Lattice '98*, Boulder, Colorado, 1998.

42. P. Chen, N. Christ, G. Fleming, A. Kaehler, C. Malureanu, R. Mawhinney, G. Siegert, C. Sui, P. Vranas, Y. Zhestkov, "Quenched QCD with Domain Wall Fermions," [CU-TP-915, hep-lat/9811026]; to appear in *Proceedings of Lattice '98*, Boulder, Colorado, 1998.

43. P. Chen, N. Christ, G. Fleming, A. Kaehler, C. malureanu, R. Mawhinney, G. Siegert, C. Sui, P. Vranas, Y. Zhestkov, "The Anomaly and Topology in Quenched, QCD above T_c" [CU-TP-913]; to appear in *Proceedings of Lattice '98* , Boulder, Colorado, 1998.

44. P. Chen, N. Christ, G. Fleming, A. Kaehler, C. Malureanu, R. Mawhinney, G. Siegert, C. Sui, P. Vranas, Y. Zhestkov, "The Domain Wall Fermion Chiral Condensate in Quenched QCD," [CU-TP-913, hep lat/9811013]; to appear in *Proceedings of Lattice '98* , Boulder, Colorado, 1998.

45. D. Kharzeev, H. Satz, A. Syamtomov, G. Zinovjev, "J/ψ Photoproduction and the Gluon Structure of the Nucleon," [hep-ph/9901375], Dec. 1998, Phys. Lett. B (submitted).

46. D. Kharzeev and J. Ellis, "The Glueball Filter in Central Production and Broken Scale Invariance," [hep-ph/9811222], Phys. Lett. B. (submitted).

47. R. D. Pisarski and D. Rischke, "A First Order Transition to, and then Parity Violation in, a Color Superconductor," [nucl-th/9811104]; Nov. 1998.

48. J. T. Lenaghan and D. Rischke, "The O(N) Model at Finite Temperature: Renormalization of the Gap Equations in Hartree and Large-N Approximation," [nucl-th/9901049].

49. S. Sasaki and O. Miyamura, "Topological Aspect of Abelian Projected SU(2) Lattice Gauge Theory," [hep-lat/9811029], Phys. Rev. D. (submitted).

50. J. Schaffner-Bielich and J. Randrup, "DCC Dynamics with the SU(3) Linear Sigma Model," [nucl-th/9812032].

51. K. Schertler, S. Leupold and J. Schaffner-Bielich, "Neutron Stars and Quark Phases in the NJL Model," [UGI-98-41, astro-ph/9901152], Jan. 1999.

52. T. Blum, A. Soni, and M. Wingate, "Calculation of the Strange Quark Mass Using Domain Wall Fermions," [hep-lat/9902016], Phys. Rev. D (submitted).

53. T. Blum, "QCD with Domain Wall Quarks," to appear in *Proceedings YKIS '98*, Kyoto, Japan.

54. D. Boer, Investigating the Origins of Transverse Spin Asymmetries at RHIC," [hep-ph/9902255], Feb. 1999.

55. R. L. Jaffe and D. Kharzeev, "X_2 Production in Polarized pp Collisions at RHIC: Measuring ΔG and Testing the Color Octet Model," [hep-ph/9903280], March 1999, Phys. Lett. B (in press).

56. H. Fujii and D. Kharzeev, "Long-Range Forces of QCD," [hep-ph/9903495], March 1999, Phys. Rev. D (submitted).

57. D. Kharzeev, "Observables in J/ψ Production," to appear in *Proceedings of Quarkonium Production in Relativistic Nuclear Collisions*, Ed. D. Kharzeev, RIKEN BNL Research Center, 1999.

58. R. Pisarski and D. H. Rischke, "Superfluidity in a Model of Massless Fermions Coupled to Scalar Bosons," Physical Review D (submitted).

59. N. K. Glendenning and J. Schaffner-Bielich, "First Order Kaon Condensate,"Physical Review C (submitted).

60. Daniël Boer, "Intrinsic Transverse Momentum and Transverse Spin Asymmetries," to appear in the *Proceedings of the 7th International Workshop on "Deep Inelastic Scattering and QCD," (DIS99)* DESY-Zeuthen, April 19-23, 1999. Nuclear Physics B (Proc. Suppl.) (to be published).

Weekly Seminars

Spin Physics	Tuesdays (10:00 a.m.)	Organized by N. Saito and W. Vogelsang
High Energy-RIKEN Theory Seminars	Wednesdays (1:30 p.m.)	Organized jointly with BNL Theorists
QCD and RHIC Physics	Thursdays (12:30 p.m.)	Organized by T. Blum
High Energy Theory Lunch Talks	Fridays (12:00 Noon)	Organized by S. Dawson
Nuclear Physics Seminars	Fridays (2:00 p.m.)	Organized by BNL Staff

Proceedings of RIKEN BNL Research Center Workshops

Volume 1 Open Standards for Cascade Models for RHIC (BNL-64912)
June 23-27, 1997 — Organizer: Miklos Gyulassy

Volume 2 Perturbative QCD as a Probe of Hadron Structure (BNL-64723)
July 14-25, 1997 — Organizers: Robert Jaffe and George Sterman

Volume 3 Hadron Spin-Flip at RHIC Energies (BNL-64724)
July 21-August 22, 1997 — Organizers: Elliot Leader and Larry Trueman

Volume 4 Non-Equilibrium Many Body Dynamics (BNL-64912)
September 23-25, 1997 — Organizers: Michael Creutz and Miklos Gyulassy

Volume 5 Color Superconductivity, Instantons, and Parity (Non?)-Conservation at High Baryon Density (BNL-65105)
November 11, 1997 — Organizer: Miklos Gyulassy

Volume 6 Quarks and Gluons in the Nucleon (BNL-65234)
November 28-29, 1997 — Organizers: Toshi-Aki Shibata and Koichi Yazaki

Volume 7 RHIC Spin Physics (BNL-65615)
April 27-29, 1998 — Organizers: Gerry Bunce, Yousef Makdisi, Naohito Saito, Michael Tannenbaum, Larry Trueman and Aki Yokosawa

Volume 8 Fermion Frontiers in Vector Lattice Gauge Theories (BNL-65634)
May 6-9, 1998 — Organizers: Robert Mawhinney and Shigemi Ohta

Volume 9 High Density Matter in AGS, SPS and RHIC Collisions (BNL-65762)
July 11, 1998 (in conjunction with RHIC '98) — Organizers: Klaus Kinder-Geiger and Yang Pang

Volume 10 Physics of Polarimetry at RHIC (BNL-65926)
August 4-7, 1998 — Organizers: Ken Imai and Doug Fields

Volume 11 Event Generator for RHIC Spin Physics (BNL-66116)
September 21-23, 1998 — Organizers: Naohito Saito and Andreas Schäfer

Volume 12 Quarkonium Production in Relativistic Nuclear Collisions (BNL-52559)
September 28 - October 2, 1998 — Organizer: Dmitri Kharzeev

Volume 13 Physics of the 1 Teraflop RIKEN-BNL-COLUMBIA QCD Project — First Anniversary Celebration (BNL-66299)
October 16, 1998 — Organizer: Robert Mawhinney

Volume 14 Quantum Fields In & Out of Equlibrium (BNL-52560)
October 26-30, 1998 — Organizers: Dan Boyanovsky, Hector De Vega and Rob Pisarski

Volume 15 QCD Phase Transitions (BNL-52561)
November 4-7, 1998 — Organizers: Thomas Schäffer and Edward Shuryak

Volume 16 RIKEN Winter School: Structure of Hadron — Introduction to QCD Hard Processes (in preparation)
December 9-12, 1998 — Organizers: Naohito Saito, Toshi-Aki Shibata and Koichi Yazaki

Volume 17 Hard Parton Physics in High-Energy Nuclear Collisions (in preparation)
March 1-5, 1999 — Organizers: James Carroll, Raju Venugopalan, Charles Gale, and Michael Tannenbaum

Volume 18 Event Generator for RHIC Spin Physics (in preparation)
March 15-19, 1999 — Organizers: Naohito Saito and Andreas Schäfer

Volume 19 Numerical Algorithms at Non-Zero Chemical Potential (in preparation)
April 27 - May 1, 1999 — Organizers: Thomas Blum and Michael Creutz

RIKEN BNL RESEARCH CENTER UPCOMING WORKSHOPS

Date:	May 25-29, 1999
Title:	Gauge Invariant Observables in Gauge Theories
Organizers:	Pierre van Baal (Leiden)
	Peter Orland (Baruch College)
	Rob Pisarski (BNL)

Date:	July 8-16, 1999
Title:	OSCAR II: Predictions for RHIC
Organizers:	Yang Pang
	Miklos Gyulassy

Date:	August 18, 1999
Title:	Coulomb and Pion-Asymmetry Polarimetry and Hadronic *Spin Dependence At RHIC Energies*
Organizers:	Elliot Leader

RIKEN · BNL · Columbia

Quantum Chromodynamics (QCD) Project

List of the world's top 12 most powerful computing sites

1) **4088.76 Gflops** - (18-JUN-1998) [NSA]

2) **2225.28 Gflops** - (03-SEP-1998) [SANDIA]

3) **2000 Gflops** - (16-JUN-1998) [ONR]

4) **1585.99 Gflops** - (08-SEP-1998) [LANL]

Gov't Comm Hqts

5) **1360 Gflops** - (13-JUL-1998) [GCHQ]

6) **1222.32 Gflops** - (20-AUG-1998) [JPL-CALTECH]

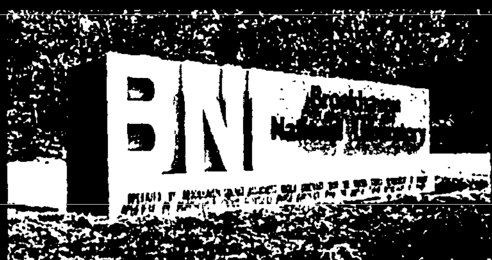
7) **1181.97 Gflops** - (04-SEP-1998) [LLNL]

8) **1080 Gflops** - (27-AUG-1998) [C]

9) **1000 Gflops** - (16-JUN-1998) [BMDO]

10) **1000 Gflops** - (04-SEP-1998) [IRVINE SENSORS]

11) **792 Gflops** - (05-NOV-1997) [METO]



12) **665.6 Gflops** - (11-SEP-1998) [BNL]
    1) Riken/BNL QCDSP/12288 614.4 Gflops
    2) Riken/BNL QCDSP/1024 51.2 Gflops

14-SEP-1998

1) 4088.76 - (18-JUN-1998) [NSA]

Sandia National Laboratories

2) 2225.28 - (03-SEP-1998) [SANDIA]

Office of Naval Research

800 N. Quincy St., Arlington, VA 22217-5660

3) 2000 - (16-JUN-1998) [ONR]

Los Alamos

4) 1585.99 - (08-SEP-1998) [LANL]

Gov't Comm Hqts

5) 1360 - (13-JUL-1998) [GCHQ]

6) 1222.32 - (20-AUG-1998) [JPL-CALTECH]

7) 1181.97 - (04-SEP-1998) [LLNL]

RIKEN · BNL · Columbia

Quantum Chromodynamics (QCD) Project

8) 1100.8 - (11-SEP-1998) [BNL]

RIKEN-BNL-Columbia (QCD) Project

1) Columbia University Center	QCDSP/8192	409.6
2) Riken/Brookhaven Natl Lab	QCDSP/12288	614.4
3) Columbia University Center	QCDSP/1024	51.2
4) Riken/Brookhaven Natl Lab	QCDSP/512	25.6

東京大學

The University of Tokyo

9) 1080 - (27-AUG-1998) [C]

BMDOLINK

BALLISTIC MISSILE DEFENSE ORGANIZATION

10) 1000 - (16-JUN-1998) [BMDO]

14-SEP-1998

RIKEN • BNL • Columbia

Quantum Chromodynamics (QCD) Project

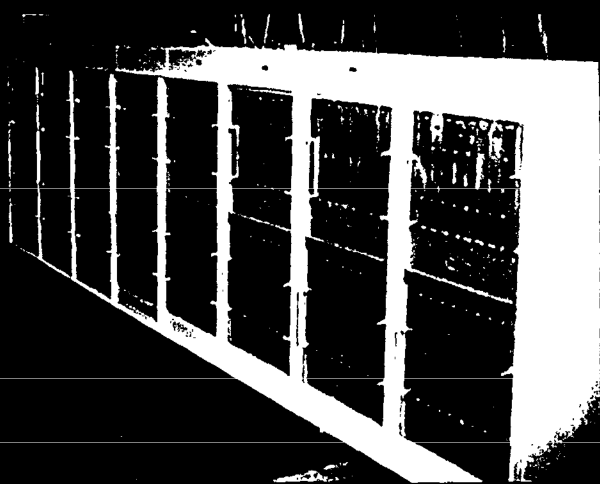
Quantum Chromodynamics (QCD) Project

Total Peak Speed: 1100.8 Gflops

Given the enormous computational demands of quantum field theory and the easily parallelized nature of this problem, it is natural to design and build massively parallel machines whose design is optimized for this type of calculation.

The QCDSP *(Quantum Chromodynamics on Digital Signal Processors)* computers designed at Columbia are such machines.

RIKEN • BNL Research Center



Columbia University Center

SC98

Gordon Bell Prize "WINNER" for Price Performance

Brookhaven
National Laboratory

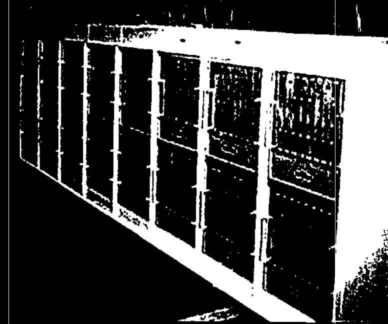
RIKEN • BNL • Columbia
Quantum Chromodynamics (QCD) Project

Speed:
Total peak speed of 1.1 Teraflops

Foot Print:
Total space occupies about 135 square feet

Architecture:
The QCDSP *(Quantum Chromodynamics on Digital Signal Processors)* computers were designed at Columbia

Columbia University



Sandia
National Laboratory

Speed:
Averaging about 1.8 trillion calculations per second

Foot Print:
Occupies about 1,600 square feet

Architecture:
Intell

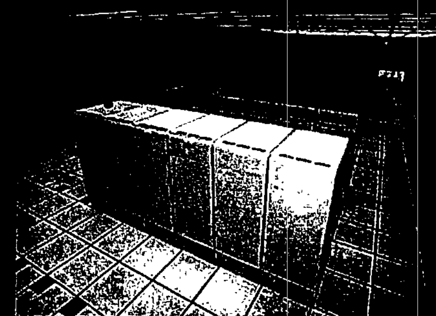
Los Alamos
National Laboratory

Speed:
Peak speed of at least 3 teraOps

Foot Print:
Occupies about 11,000 square feet

Architecture:
SGI

Lawrence Livermore
National Laboratory



Speed:
Over 2.6 TFLOP/s of peak performance

Foot Print:
Occupies about 8,000 square feet

Architecture:
IBM


SC98 Gordon Bell Prize Finalist
for Price Performance


SC98 Gordon Bell Prize
for Price Performance
WINNER!
Gordon
Bell
SC98

Major problems

- CP violation
- Lack of precision QCD calculations

$$\frac{\dfrac{\text{Rate}\,(K_L^0 \to \pi^+\pi^-)}{\text{Rate}\,(K_S^0 \to \text{''}\ )}}{\dfrac{\text{Rate}\,(K_L^0 \to \pi^0\pi^0)}{\text{Rate}\,(K_S^0 \to \text{''}\ )}} = \left|\frac{\epsilon + \epsilon'}{\epsilon - 2\epsilon'}\right|^2 \cong 1 + 6\,\mathrm{Re}(\epsilon'/\epsilon)$$

$$\mathrm{Re}\,(\epsilon'/\epsilon) \times 10^4$$

	experimental results	theoretical estimates (based on CKM matrix)
•	28 ± 4 (FNAL)	$4.6 \pm 3.0 \pm 0.4$ (Rome '97)
•	$23 \pm 3.6 \pm 5.4$ (NA31)	3.6 ± 3.4 (Munich '97) (10.4 ± 8.3 if $m_s \sim 100$ Mev)
	$7.4 \pm 5.2 \pm 2.9$ (E731)	17^{+14}_{-10} (Trieste '98)

Reliable theoretical results are expected soon from the QCDSP group

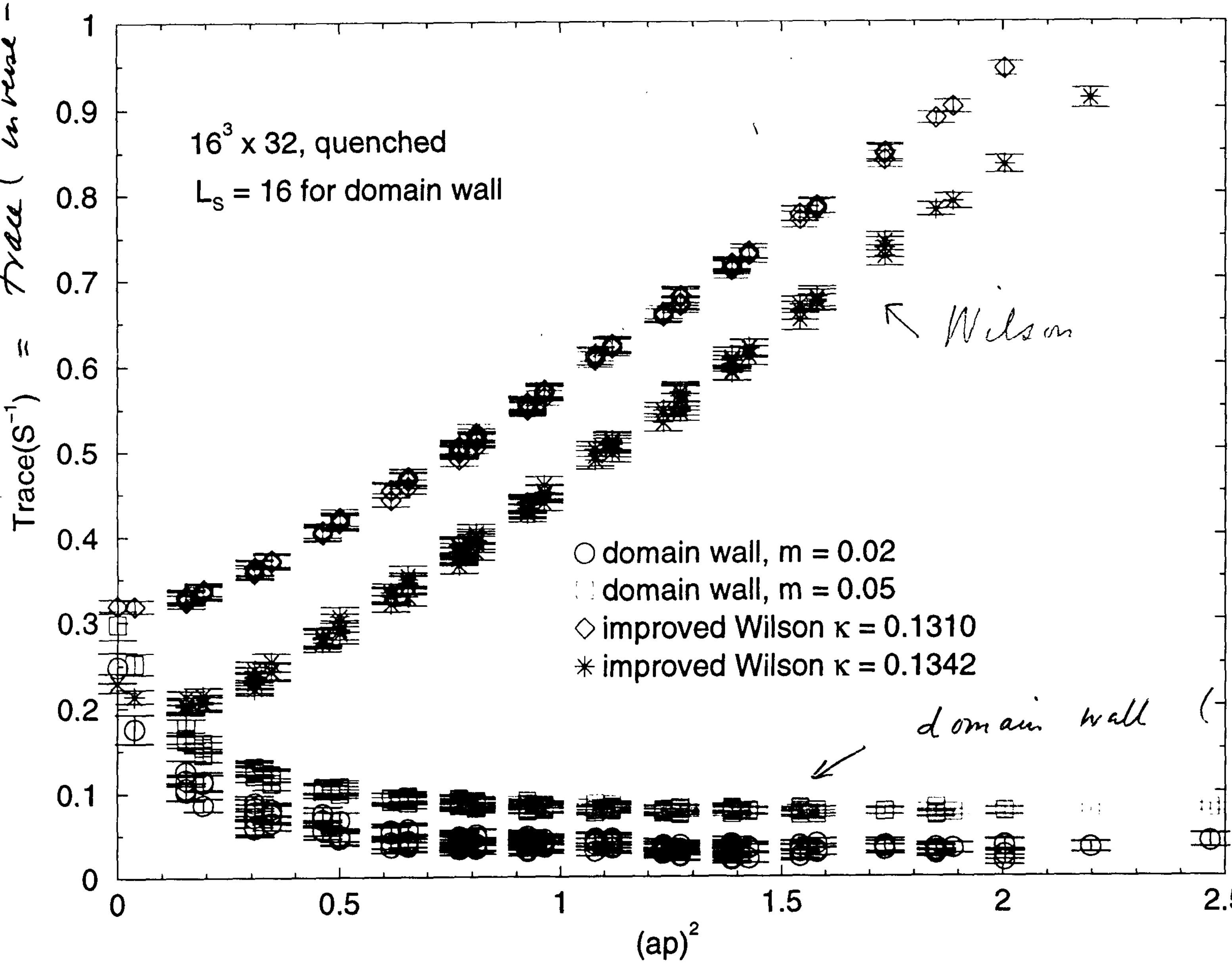
(RIKEN - BNL - Columbia) 1.1 T flops

(lattice → continuum)

Quark Mass Renormalization

RIKEN–BNL–Columbia QCD Collaboration (QCDSP)

m = trace (inverse-propagator) =



Wilson

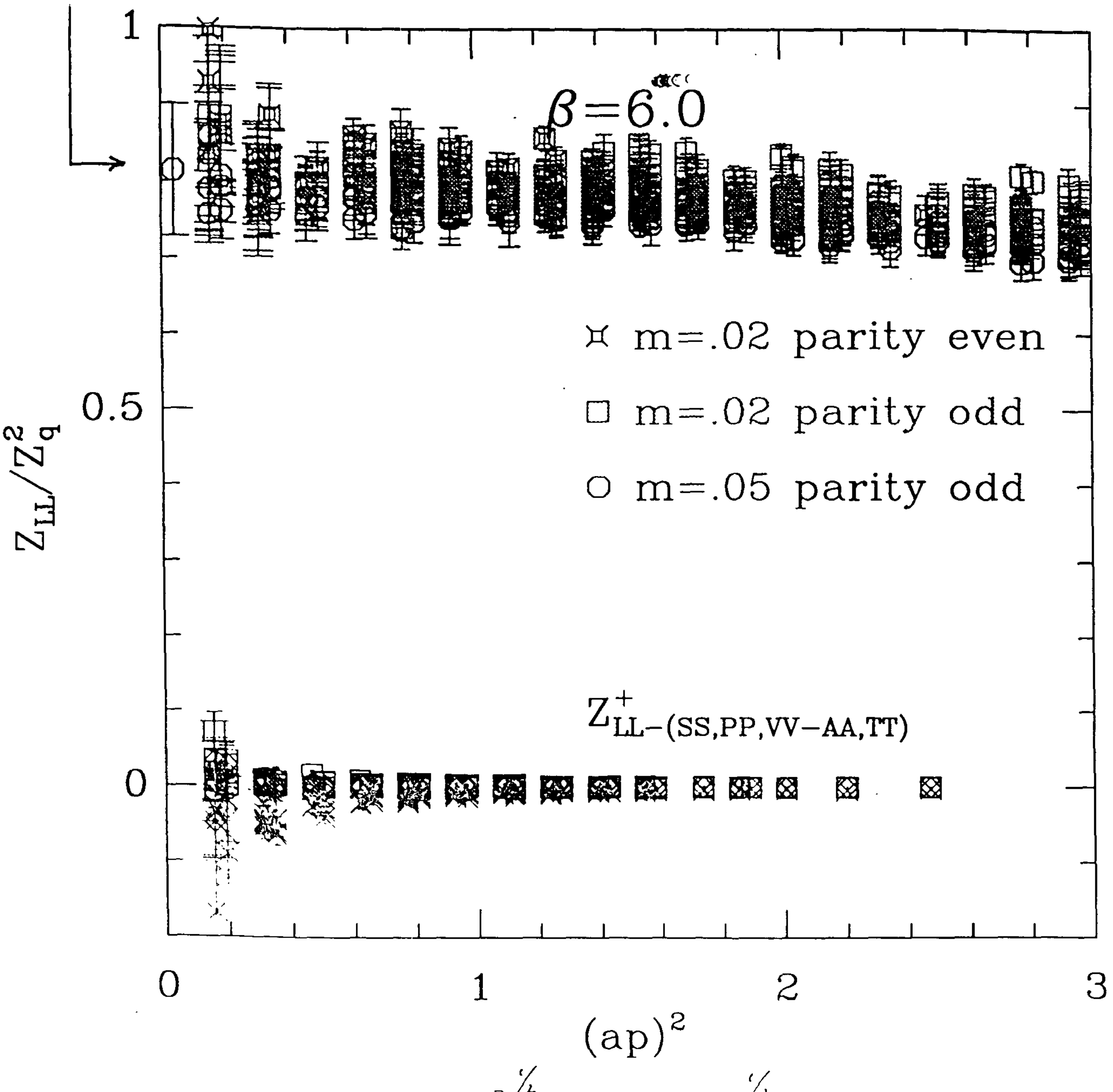
domain wall (full chiral sym.)

$m = 0.02$

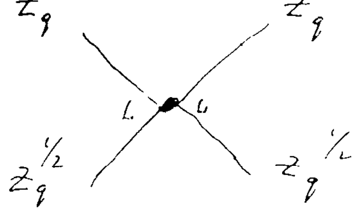
No Chiral Mixing

domain wall lattice (QCDSP)

$O_{LL} = (V-A)\cdot(V-A) = VV + AA - VA - AV$



4-fermion vertex



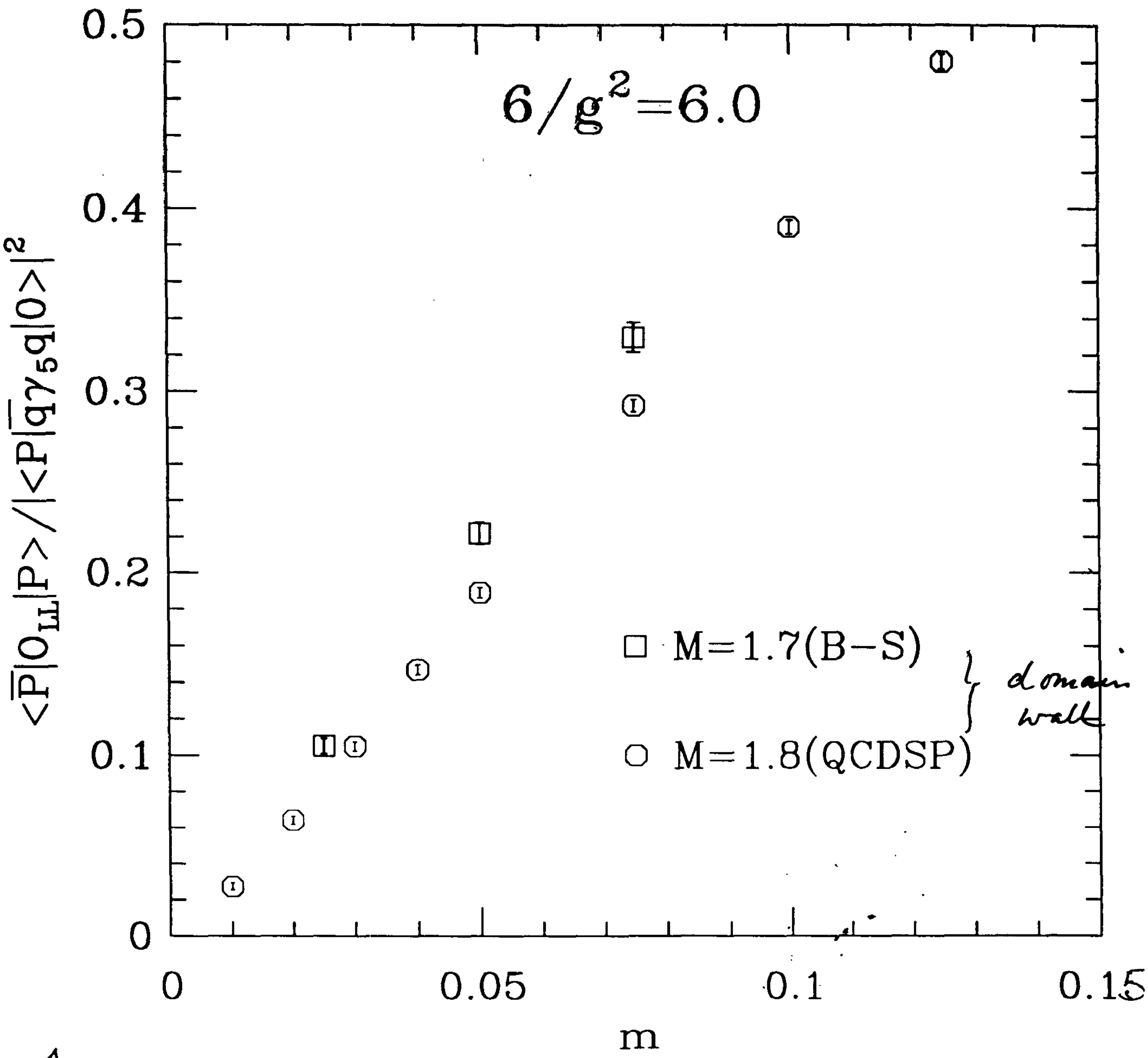
Blum

$\epsilon \propto \eta B_K$ ($\eta \equiv$ CP violating phase in CKM)

$$B_K = \frac{\langle \bar{K} | O_{LL} | K \rangle}{\frac{8}{3} f_K^2 m_K^2}$$

$$O_{LL} = \bar{s} \gamma_\mu (1-\gamma_5) d \, \bar{s} \gamma_\mu (1-\gamma_5) d$$

P = pseudoscalar



domain wall

As $m \to 0$
$\langle \bar{P} | O_{LL} | P \rangle \to 0$ (and $m_K \to 0$)

A Possible Probe

parity violation per RHIC

collision to detect coherence:

$0(x)_{\mathcal{P}}$ is parity odd

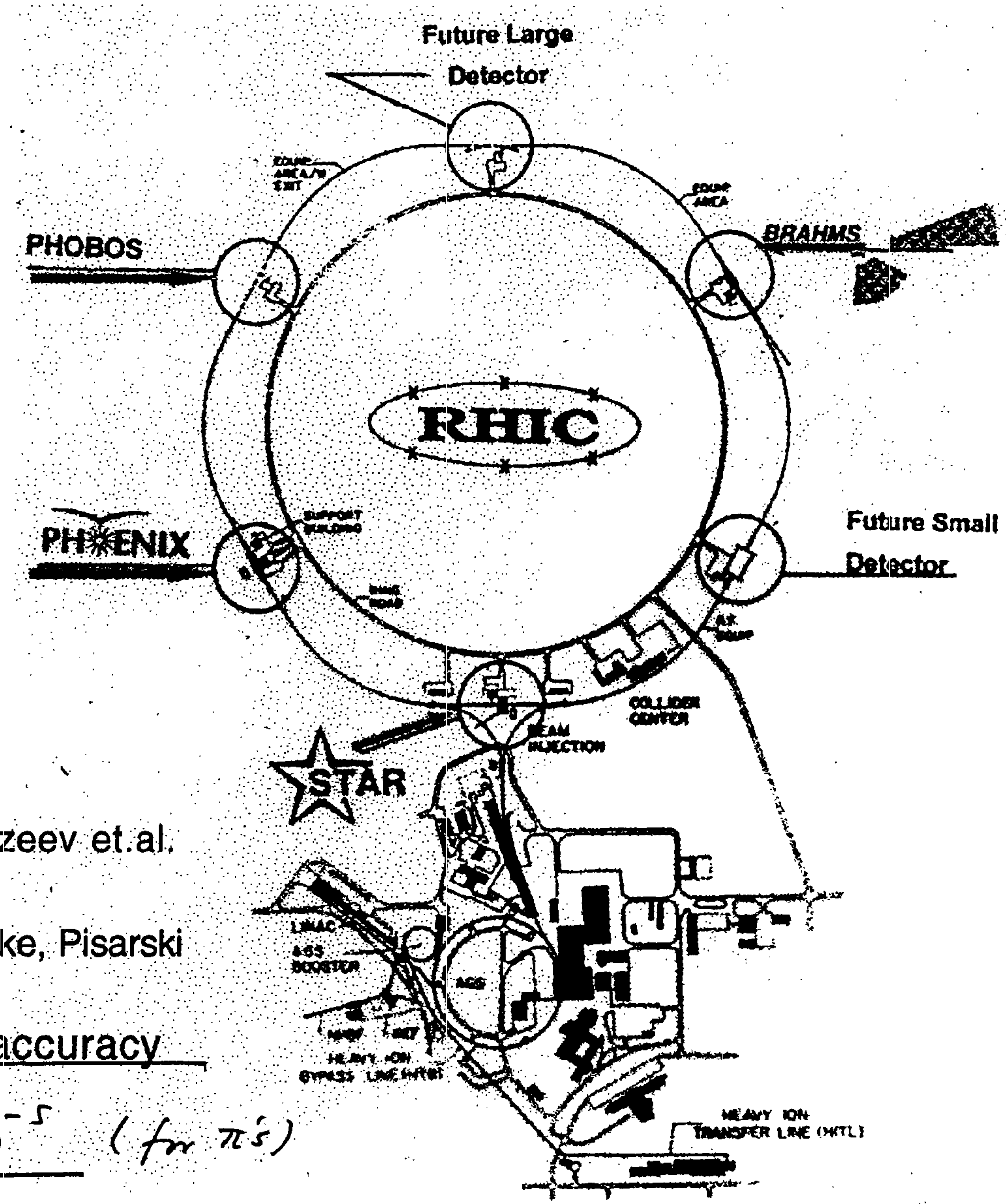
$\langle 0(x) \rangle_{\mathcal{P}} \neq 0$ per collision

over $|x| \sim 5$ fm

$\overline{\langle 0(x) \rangle_{\mathcal{P}}} = 0$ over all collisions

examples: 1. $0_{\mathcal{P}} = \vec{E} \cdot \vec{B}$ Kharzeev et.al.

or 2. $0_{\mathcal{P}} = qq$ in $\overline{3}$ Rischke, Pisarski



signal	experimental accuracy
$(\vec{k}_1 \times \vec{k}_2) \cdot \vec{k}_3$	$10^{-4} - 10^{-5}$ (for π's)
$\vec{\sigma}_\Lambda \cdot \hat{p}_\pi$ in $\Lambda^0 \to p\,\pi^-$	10^{-1}

New Tenure Track Strong Interaction Theory

RHIC Physics Fellow Program

- Each Fellow spends half time at RBRC and half at the participating institution

- Each participating institution must hold a tenure track position in strong interaction physics

  (high energy nuclear theory, RHIC phenomenology, perturbative and lattice QCD, hadronic spin physics, hadronic spectra and their transition matrix elements)

- At present there are nine participating institutions:

  Arizona, BNL**, UCLA*, Connecticut *, Ohio State, Illinois (in Chicago)*, SUNY (Stony Brook)**, Yale**, Columbia*

**Offer accepted
*Offer made (or in progress)

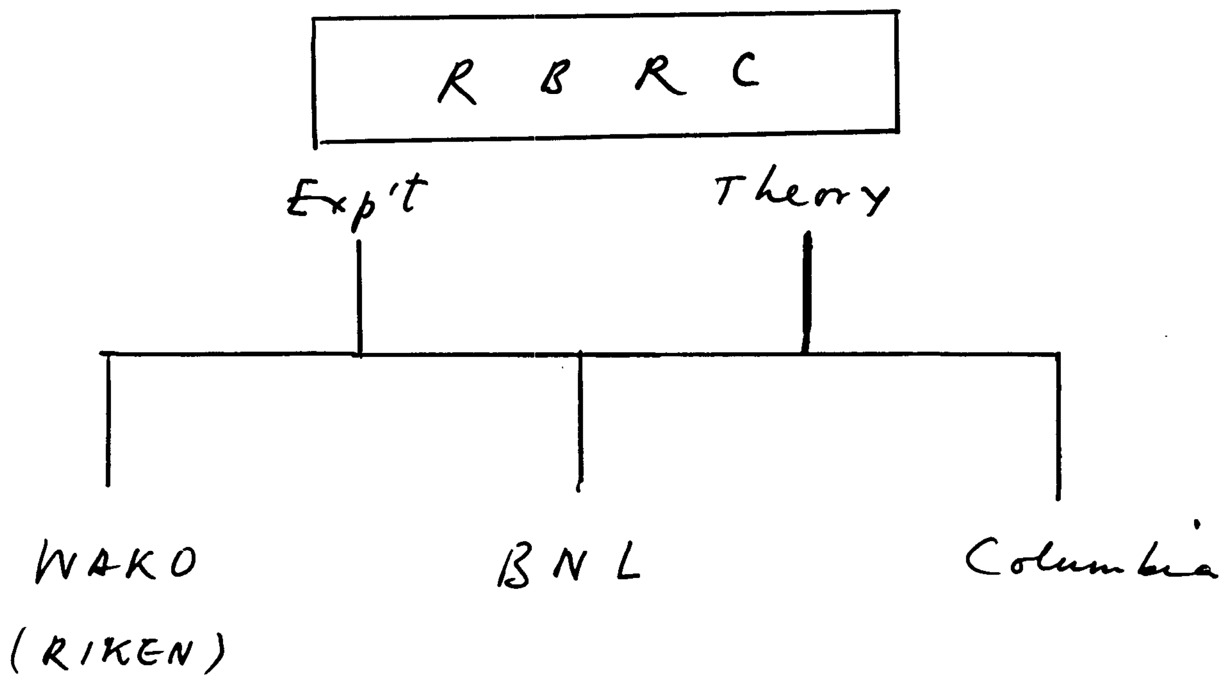
RBRC Research Scientists '99 – '00
(Theory)

post docs	D. Boer	
	Y. Nara	
	S. Sasaki	
	J. Schaffner-Bielich	
	M. Wingate	
	Y. Yasui	
Fellows	T. Blum	
	D. Rischke	
Tenure track/RHIC Fellows	D. Kharzeev	(BNL)
	* A. Kusenko	(UCLA)
	T. Schaefer	(SUNY-SB)
	* D. Son	(Columbia)
	* M. Stephanov	(U. Ill. Chicago)
	* X. N. Wang	(U. Connecticut)
	T. Wettig	(Yale)

no. increase by $7 \times \frac{1}{2} - 1 = 5 \times \frac{1}{2} = 2\frac{1}{2}$ (from '98 → '99)
Amp " from $9 \rightarrow 11.5$

expected scientific productivity $\frac{'99-}{'98} \cong \left(\frac{9+2.5}{9}\right)^2 = 1.63$

*in progress


R B R C
Exp't
Theory
WAKO
(RIKEN)
BNL
Columbia

Experimental

RHIC SPIN.

Collider: PP 250 GeV x 250 GeV.
70% Polarization
Longitudinal &
Transverse

Detector: Phenix
Muon Arm.

RBRC - Experimental Group

Group Leader: M. Ishihara.
Deputy Gp Leader: J. Bunce.
Scientific Staff:
Fellow: M. Grosse Perdekamp
Post doc: A. Bazilevsky

+
(1-2 next year)
(April '99 - March '00)

Other Components.

Theoretical (Spin)

R. Jaffe.
L. Trueman
G. Sterman
W. Vogelsang

Riken (Exptl)

N. Saito
K. Kurita.
T. Ichihara. } CCJ
Y. Watanabe.

Discussion Groups.

Tuesday: Morning: Spin Discussion
Afternoon: Round table.

Thursday: Luncheon: Theory/Exp't.

Workshops: 6/(12) [#7 - #18]

Visitors: Japanese Universities
BNL: Physics Dep't
Offices: Contiguous

THEORY PRESENTATIONS

Kaon Weak Matrix Elements with Domain Wall Quarks

Thomas Blum

Lattice QCD with Domain Wall Quarks

- Quenched QCD, $\beta = 6.0$, $16^3 \times 32 \times 16$, $m = 0.01 - 0.125$

- 50% of RIKEN BNL QCDSP (3×100 GFLOPS)

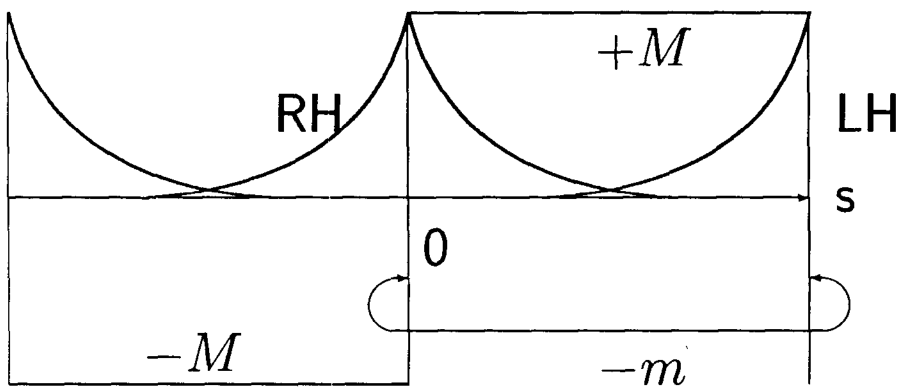
- Kaon weak matrix elements (Blum)

- Spectrum and quark masses (Wingate)

- Negative parity baryon spectrum (Sasaski)

DOMAIN WALL QUARKS

- **Kaplan**: Add extra *5th dimension* with mass defect, or domain wall. **4d Chiral zero modes** bound to domain wall.



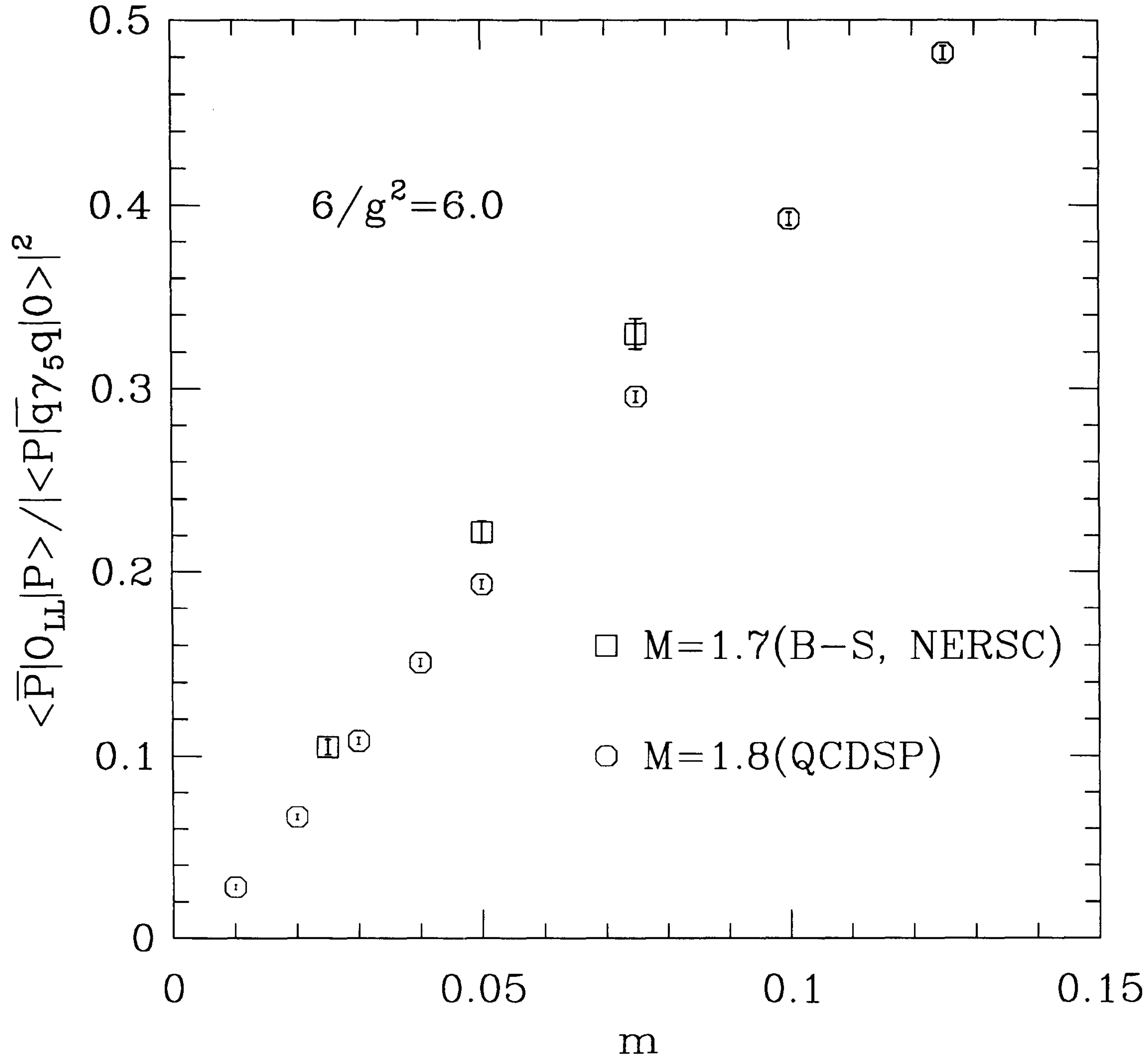
- **Shamir**: couple both Weyl fermions to **same 4d gauge field** and simulate **vector** theory(QCD).
- **Chiral symmetry** is manifest, left-handed and right-handed quarks are globally separated in the 5th dimension. Explict breaking from quark mass m same as in continuum.
- **Overlap** induces exponentially small additive quark mass. Chiral limit: $N_s \to \infty$, $m_{quark} = mM(2 - M) \to 0$.

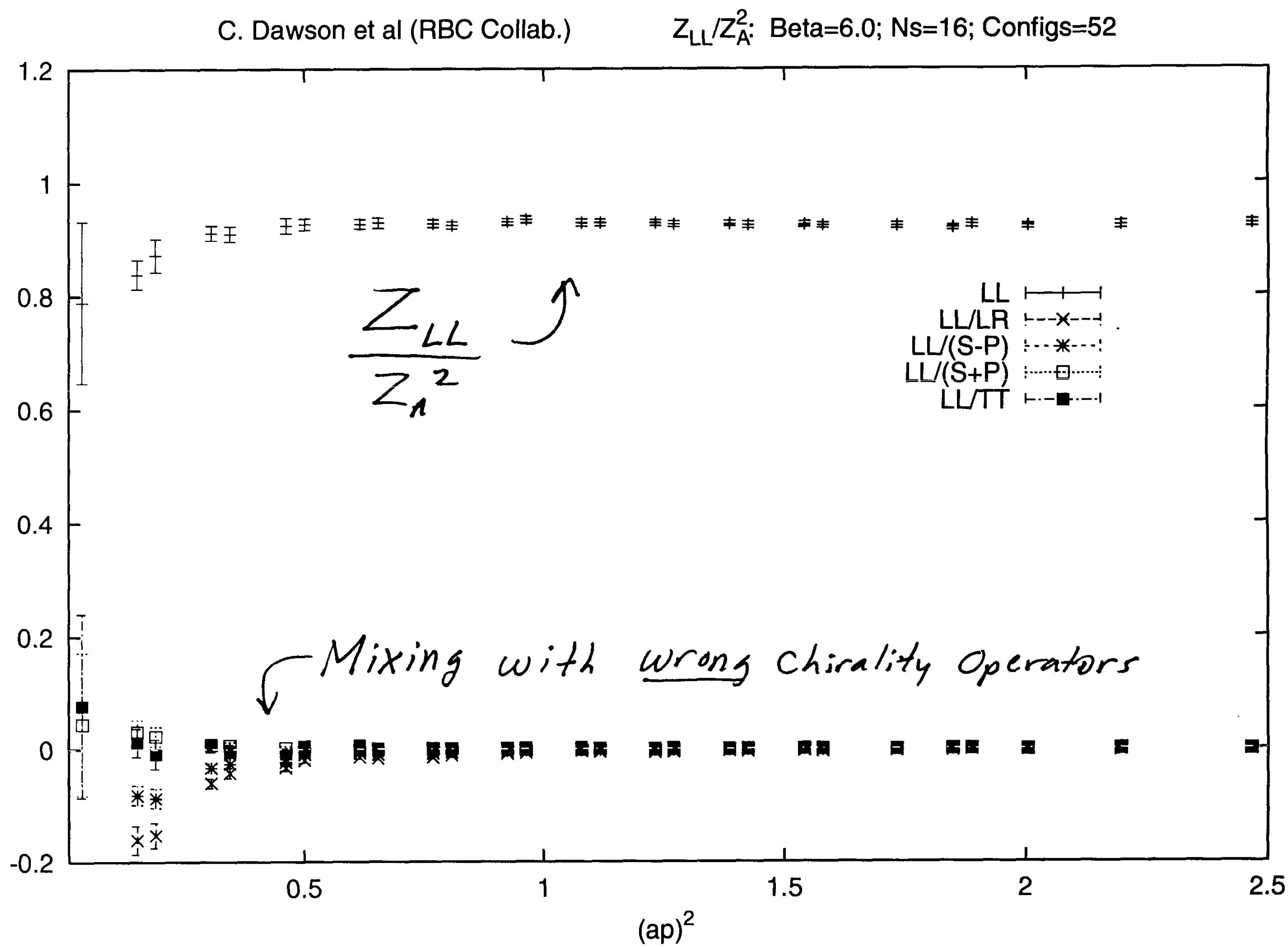
$O_{LL} \sim \Delta S=2$, $K^0-\bar{K}^0$ Mixing

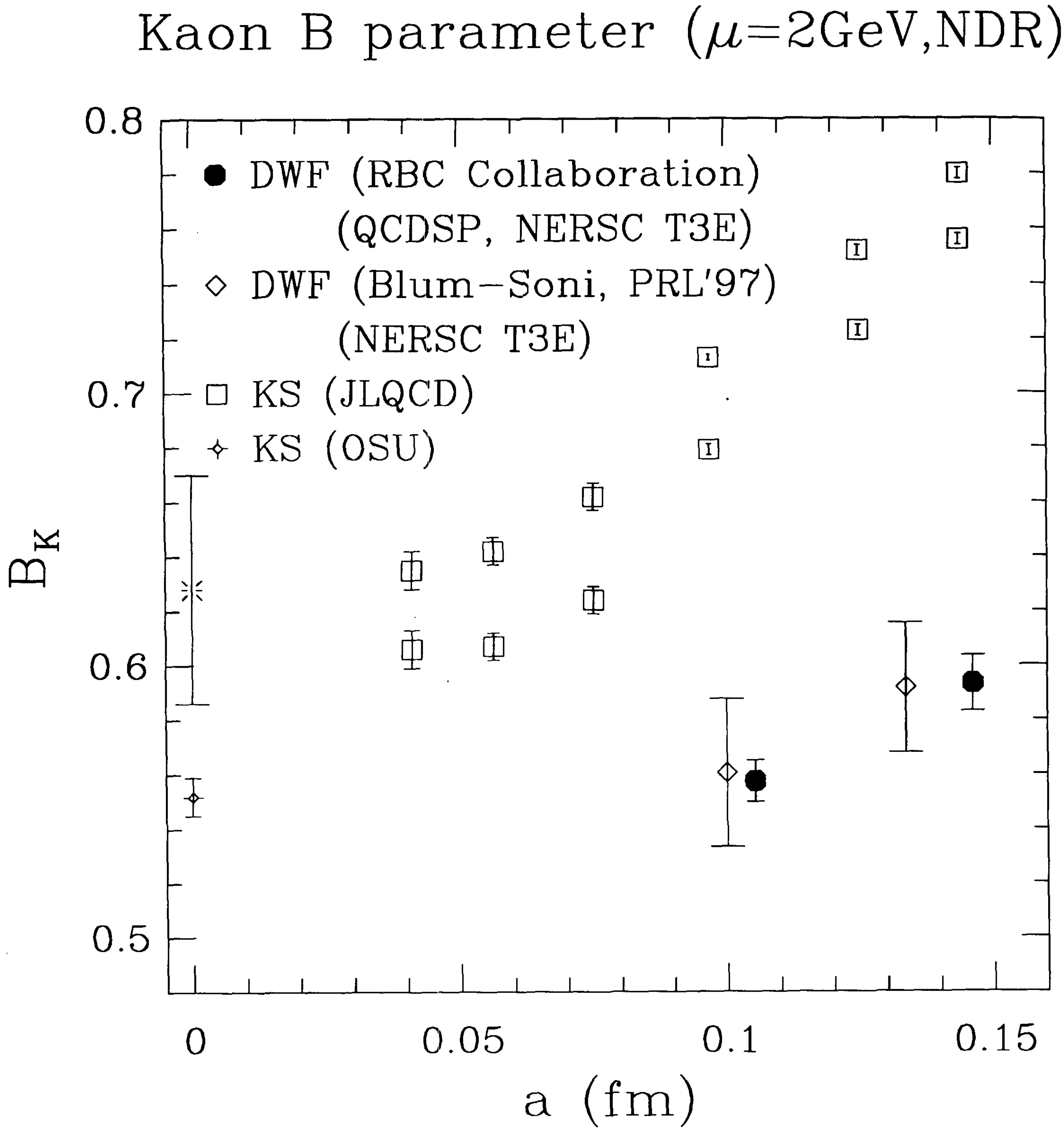
$\epsilon \longrightarrow$ Indirect CP violation

Should vanish as $\underline{m \to 0}$, χS

RBC Collaboration



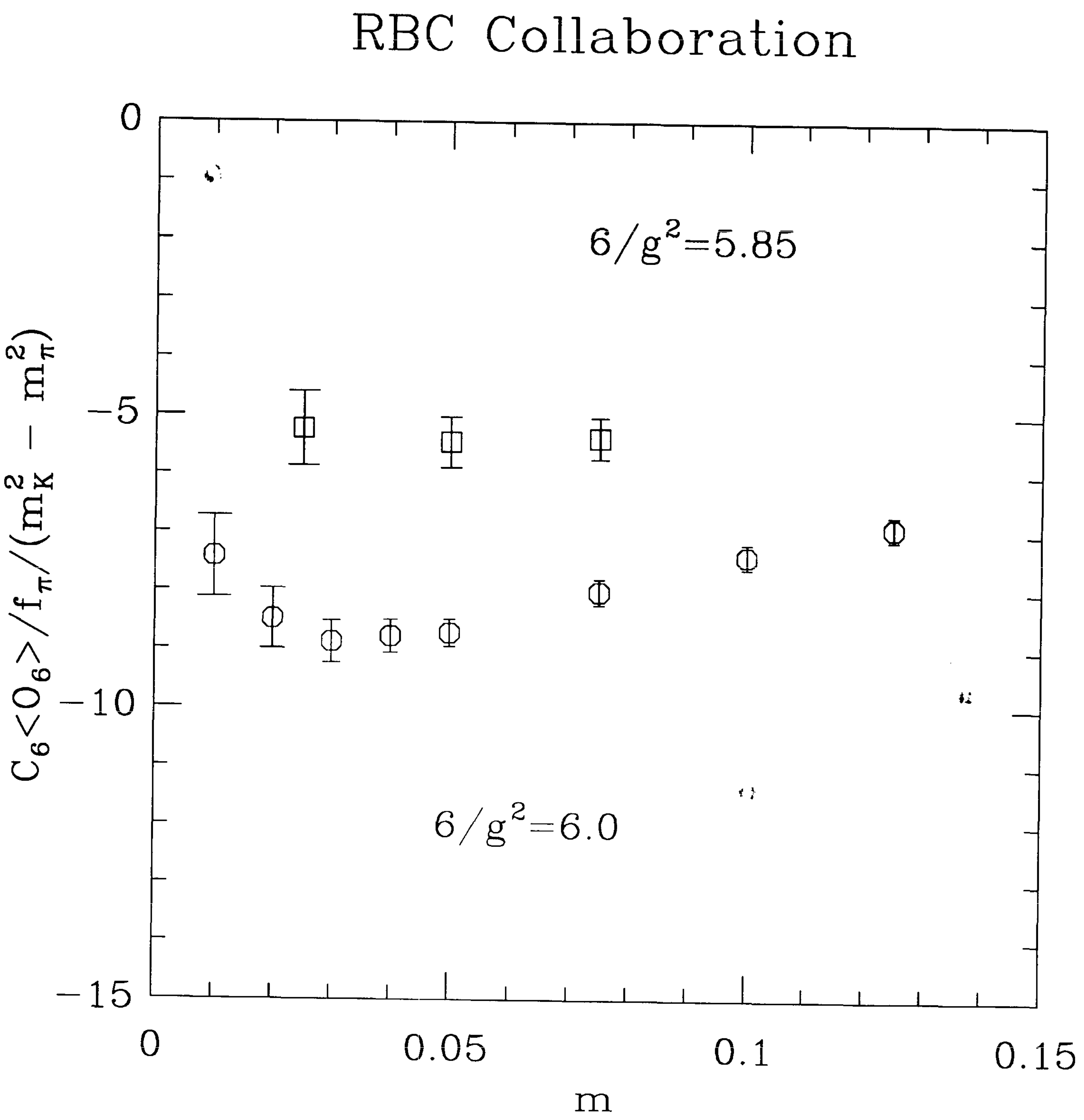

C. Dawson et al (RBC Collab.)
Z_{LL}/Z_A^2: Beta=6.0; Ns=16; Configs=52
LL
LL/LR
LL/(S-P)
LL/(S+P)
LL/TT
$\frac{Z_{LL}}{Z_A^2}$
Mixing with wrong chirality operators
(ap)^2
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0.5
1
1.5
2
2.5



Kaon B parameter (μ=2GeV,NDR)
DWF (RBC Collaboration)
(QCDSP, NERSC T3E)
DWF (Blum−Soni, PRL'97)
(NERSC T3E)
KS (JLQCD)
KS (OSU)
B_K
0.8
0.7
0.6
0.5
0
0.05
0.1
0.15
a (fm)

$\langle \pi\pi | O_6 | K \rangle = \langle \pi | O_6 | K \rangle + \langle 0 | O_6 | K \rangle$

Important for ϵ', direct CP



SUMMARY

- DWF promising alternative to conventional lattice fermion for lattice QCD calculations (weak matrix elements, renormalization, quark mass, ...

- Extensive spectrum-weak matrix element-nonperturbative renormalization calculation under way on the *RIKEN BNL Research Center* **QCDSP supercomputer** and *NERSC* **T3E**

- Future goals: Nucleon matrix elements, dynamical simulations

The Parity Partner of the Nucleon in Quenched QCD with Domain Wall Fermions

Shoichi Sasaki

The parity partner of the nucleon in quenced QCD with domain wall fermions

Shoichi Sasaki

(RIKEN-Brookhaven-Columbia-Collaboration)

RIKEN BNL Research Center

T. Blum, S. Ohta (KEK), S. S. , M. Wingate

Brookhaven National Laboratory

M. Creutz, C. Dawson, A. Soni

Columbia University

P. Chen, N. Christ, G. Fleming, A. Kaehler, T. Klassen, C. Malureanu, R. Mawhinney, G. Siegert, C. Sui, P. Vranas (Illinois), L. Wu, Y. Zhestkov

Ongoing subject

Survey the spectrum of the lowest-lying negative parity baryon (N*) as the parity partner of the positive parity baryon of ground state (nucleon N) by lattice QCD simulation.

Why ?

Physical reason:

Chiral symmetry and its spontaneous breakdown play important role for low energy hadron physics.

For instance:

The spontaneous chiral symmetry breaking (SSB) leads to the absence of the parity doubling in hadron spectra. Mass splittings between the parity pair of low-lying mesons, e.g. $\rho(770)$ and $a_1(1260)$, would emerge as a result of SSB.

However,

the parity pair of low-lying baryons: N and N*, are NOT well understood as compared with the mesonic case. The lack of knowledge causes different theoretical predictions for properties of N* in some effective models.

(For example, πNN^* coupling and axial charge of N*)

Technical challenge:

It is hard to measure the spectrum of the negative parity baryon in lattice QCD for several reasons.

One possible reason

The unphysical mixing between the distinct baryon interpolating operators through the breaking of chiral symmetry would be crucial on the study of negative parity baryons.

However,

the domain wall discretization can cope with the chiral symmetry on the lattice.

As a result,

the implementation of domain wall fermions (DWF) could reduce the unphysical mixing problem.

How to measure the spectrum of baryon

- baryon interpolating operator : $B \sim \varepsilon_{abc}\, q^a q^b q^c$

$$G_B(t) = \sum_{\vec{x}} \langle 0 | T\{ \underset{\uparrow \atop \sum_s |B_s\rangle\langle B_s| = 1}{B(\vec{x},t)\bar{B}(0,0)} \} | 0 \rangle \xrightarrow[(\text{large } t)]{} e^{-\underset{\downarrow \atop \text{lowest-lying state}}{m_B} t}$$

Suppose the baryon two-point function is dominated by the ground state

$$G_B(t) = (1+\gamma_t)\, g(t) + (1-\gamma_t)\, g(-t)$$

where $g(t) \equiv \theta(t)\, C_B \exp\{-m_B t\}$

$\Longrightarrow$ We can extract m_B from the plateau of $\underbrace{M(t) = \ln\{g(t-1)/g(t)\}}_{\text{"Effective mass"}}$

- quantum number : J^P $\quad \left\{ \begin{array}{l} J \text{ (total spin)} \\ P \text{ (parity)} \end{array} \right.$

(1) Nucleon $\left(J^P = \frac{1}{2}^+ \right)$

TWO possible operators (the lowest twist operator)

$$B_1^+ = \varepsilon_{abc} (q^{Ta} C \gamma_5 q^b)\, q^c$$

$$B_2^+ = \varepsilon_{abc} (q^{Ta} C q^b)\, \gamma_5 q^c$$

$\Longrightarrow$ The most general operator for $\frac{1}{2}^+$ baryon must be

$B = B_1^+ + s B_2^+$ but "$s=0$" is set in lattice calculation

① B_2^+ vanishes in the non-relativistic limit

② "$s \neq 0$" only increases the statistical uncertainities

Remark on unphysical mixing between B_1^+ and B_2^+

1) The Wilson fermion induces unphysical mixing between them reflecting the breaking of chiral symmetry

$$B_1^+ \longrightarrow B_1^+ - \frac{\alpha_s}{4\pi}\{-2\log Q^2a^2 + C_1\}B_1^+ - \frac{\alpha_s}{4\pi}C_2\cdot B_2^+$$
$$B_2^+ \longrightarrow B_2^+ - \frac{\alpha_s}{4\pi}\{-2\log Q^2a^2 + C_3\}B_1^+$$

through the renomarization factor within one-loop order

$C_1 = 42.72, C_2 = 34.70, C_3 = -1.60$ (Ref.) Phys. Rev. D51 ('95) 6383. Nucl. Phys. B286 ('87) 683.

However

2) It doesn't matter in the case of the domain wall fermion (DWF

(Ref.) S. Aoki, T. Izubuchi, Y. Kuramashi, Y. Taniguchi; hep-lat/990200

$$B_1^+ \longrightarrow Z_{DWF}\left(1 - \frac{\alpha_s}{4\pi}\{-2\log Q^2a^2 + C_{DWF}\}\right)\underset{\sim}{B_1^+}$$
$$B_2^+ \longrightarrow Z_{DWF}\left(1 - \frac{\alpha_s}{4\pi}\{-2\log Q^2a^2 + C_{DWF}\}\right)\underset{\sim}{B_2^+}$$

$\Longrightarrow$ DWF can cope with the chiral symmetry on the lattice.

(2) Parity partner of nucleon $(J^P = \frac{1}{2}^-)$ ····· $N^*(1535)$

We can get TWO possible operators for $\frac{1}{2}^-$ baryon by multiplying γ_5 to B_1^+ and B_2^+

$$B_1^- = \gamma_5 B_1^+ = \varepsilon_{abc}(q_a^T C\gamma_5 q_b)\gamma_5 q_c$$
$$B_2^- = \gamma_5 B_2^+ = \varepsilon_{abc}(q_a^T C q_b) q_c$$

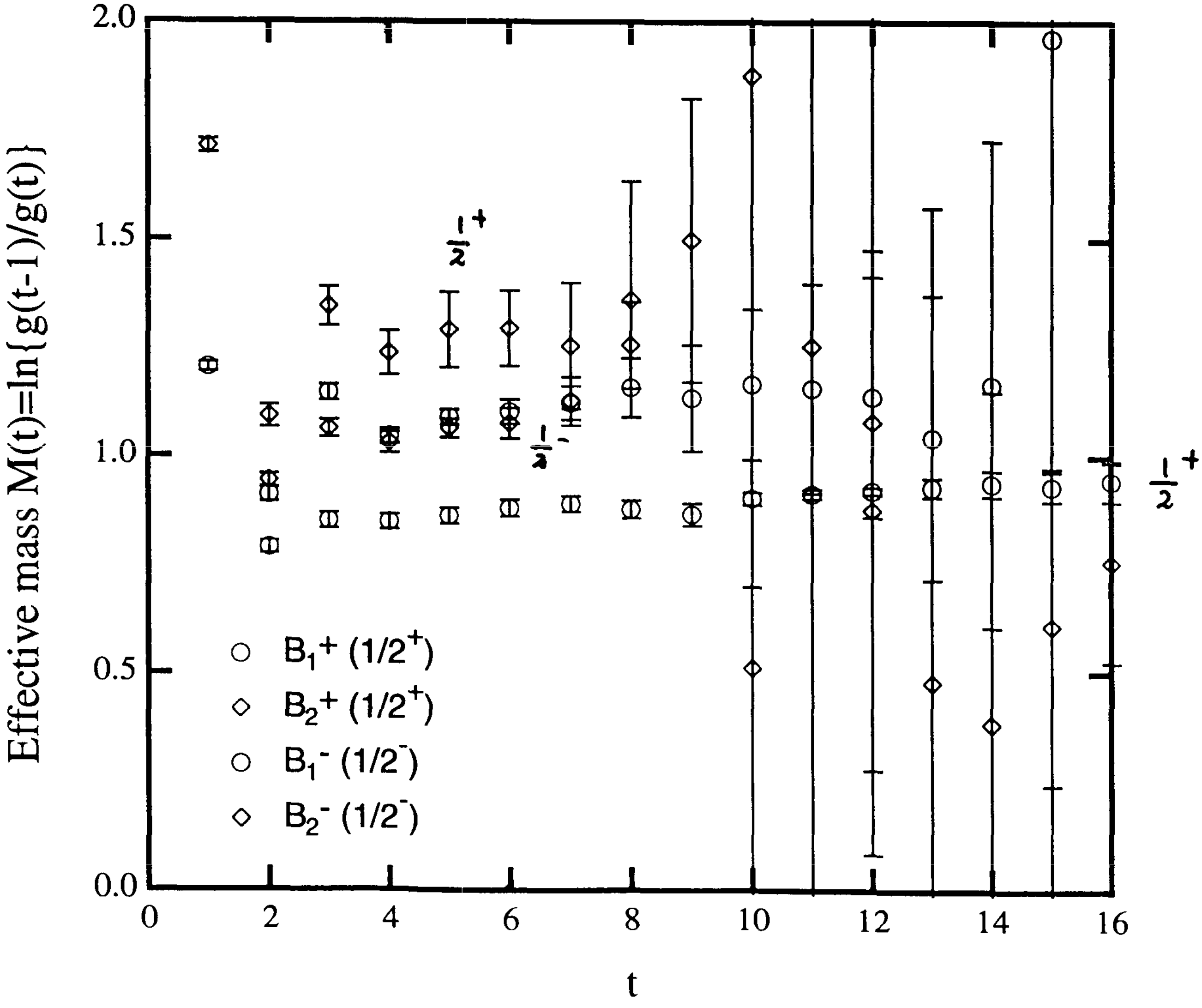
So far the difference between B_1^- and B_2^- is not precisely determined

Parameters for simulations

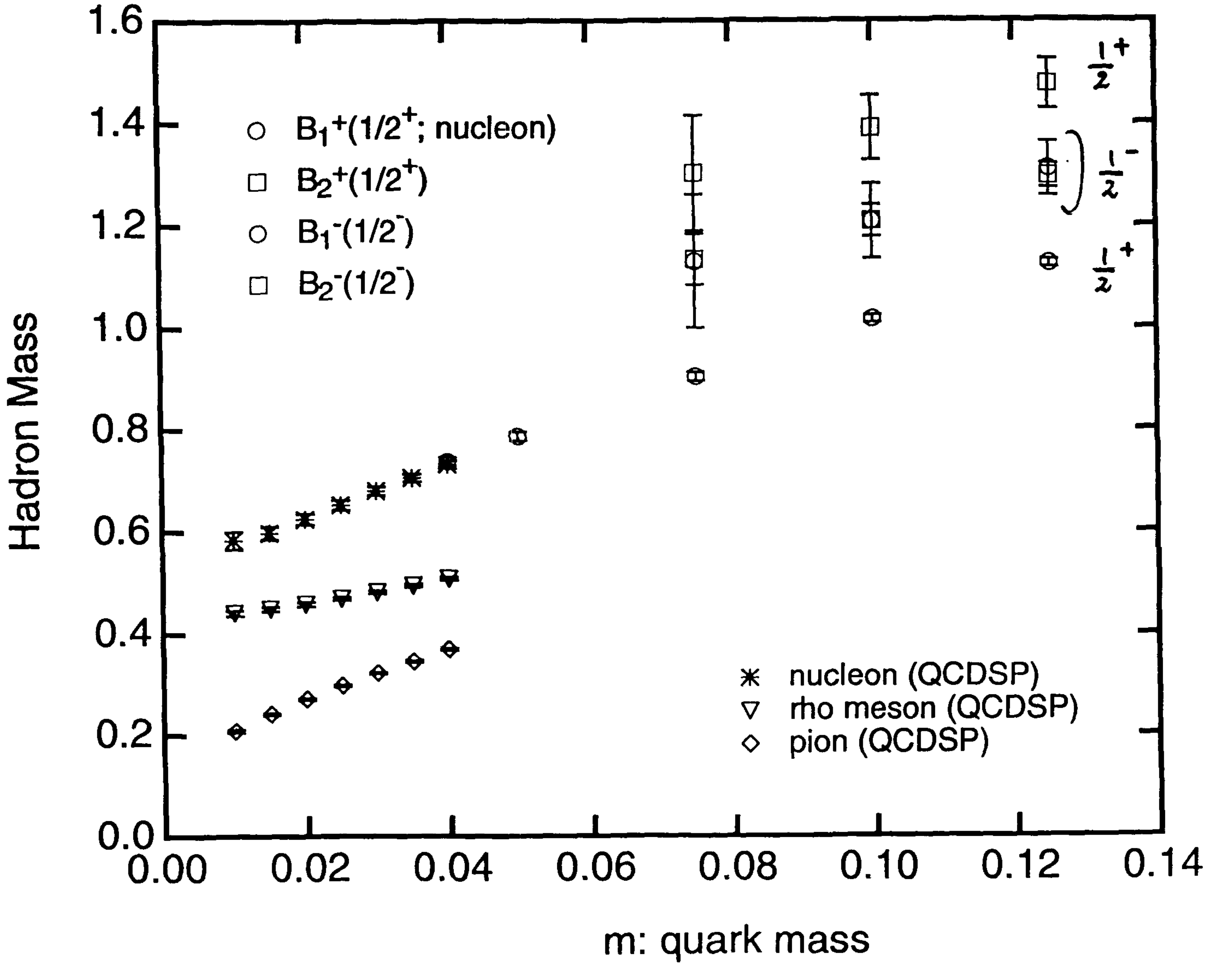
- $V = 16^3 \times 32$, $\beta = 6.0$
- $L_s = 16$, $M = 1.8$
- $m_0 = 0.075$
- Wall source ; P.B.C + A.P.B.C. (time)
- 13 config. × 2

$$B_1^+ = \varepsilon_{abc}(q_a^T C \gamma_5 q_b) q_c \ , \quad B_1^- = \gamma_5 B_1^+$$

$$B_2^+ = \varepsilon_{abc}(q_a^T C q_b) \gamma_5 q_c \ , \quad B_2^- = \gamma_5 B_2^+$$



13 configs x 2
V=16x16x16x32, beta=6.0
Ls=16, M=1.8



Quark Masses Using Domain Wall Fermions

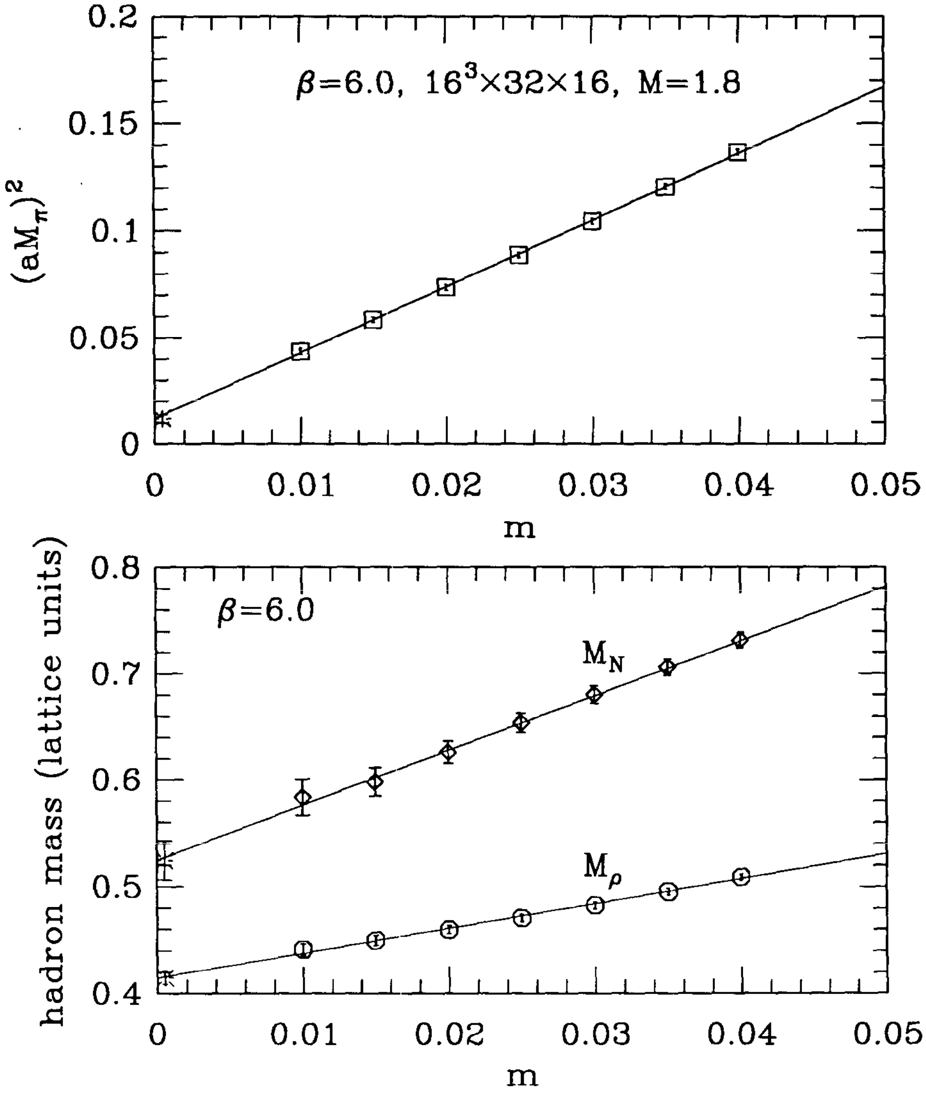
Matthew Wingate

Quark Masses using Domain Wall Fermions

Matthew Wingate

- DWF exhibit continuum–like chiral symmetries: B_K, axial Ward identities, and more
- Exploratory calculation of strange mass: Blum, Soni, M.W., (hep–lat/9809065, hep–lat/9902016)
- Ongoing RIKEN/BNL/Columbia quenched simulations with DWF: 85 config., 7 masses at $\beta = 6.0$ (QCDSP); 70 config., 3 masses at $\beta = 5.85$ (NERSC)
- Nonperturbative calculation of renormalization factors: New and important ingredient

85 configurations using RIKEN BNL QCDSP (2×100 Gflop)



In chiral limit: $M_N/M_\rho = 1.26(4)$ (expt. 1.22)

Chiral perturbation theory fits:

$$\begin{aligned} M_\pi^2 &= B_\pi m + A_\pi \\ M_\rho &= B_\rho m + A_\rho \\ M_N &= B_N m + A_N \end{aligned}$$

$A_\pi \neq 0 \Rightarrow$ systematic error, e.g. finite V, finite N_s, quenching, ...
Working ansatz: $M_\pi^2 - A_\pi$ is physical.

Renormalized lattice quark mass:

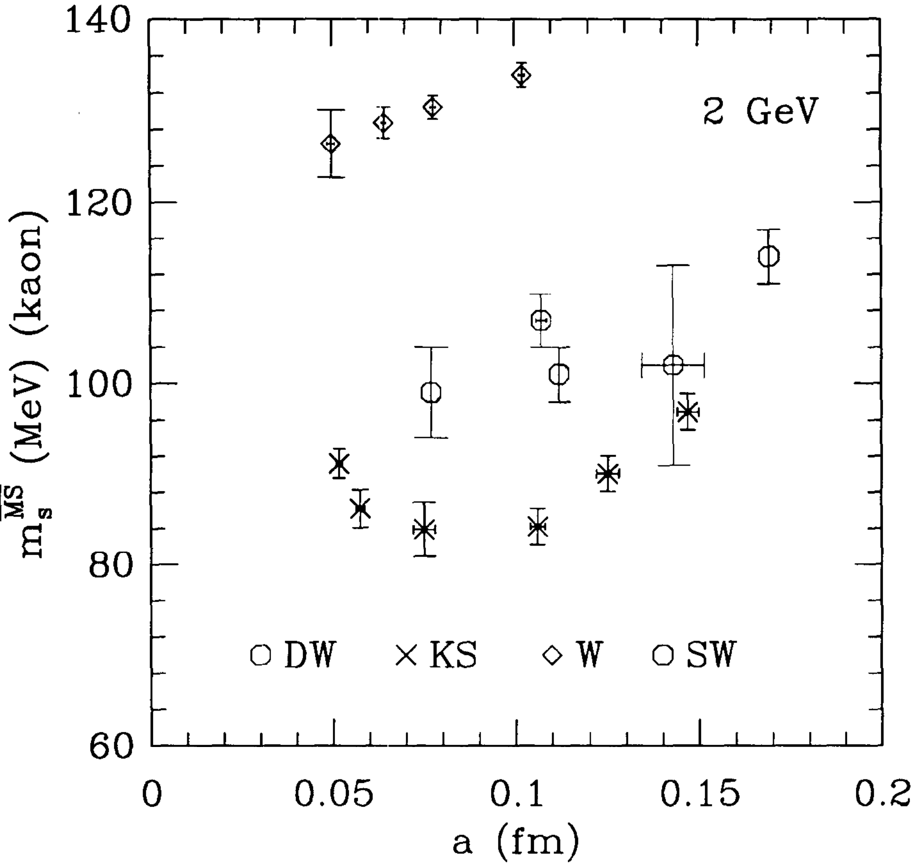
$$m^{\mathrm{LAT}}(\mu) = Z^{\mathrm{LAT}}(\mu a)\, m(a)$$

DWF: $Z^{\mathrm{LAT}}|_{\mathrm{tree}} = M(2-M)$. One–loop result Blum, Soni, M.W., (hep–lat/9809065, 9902016) S. Aoki *et al.*, (hep–lat/9810020).

Matching to continuum regularization scheme:

$$m^{\overline{\mathrm{MS}}}(\mu) = R^{\overline{\mathrm{MS}}}_{\mathrm{LAT}}(\mu)\, m^{\mathrm{LAT}}(\mu)$$

Preliminary strange quark mass, compared with other lattice actions. Statistical errors only!

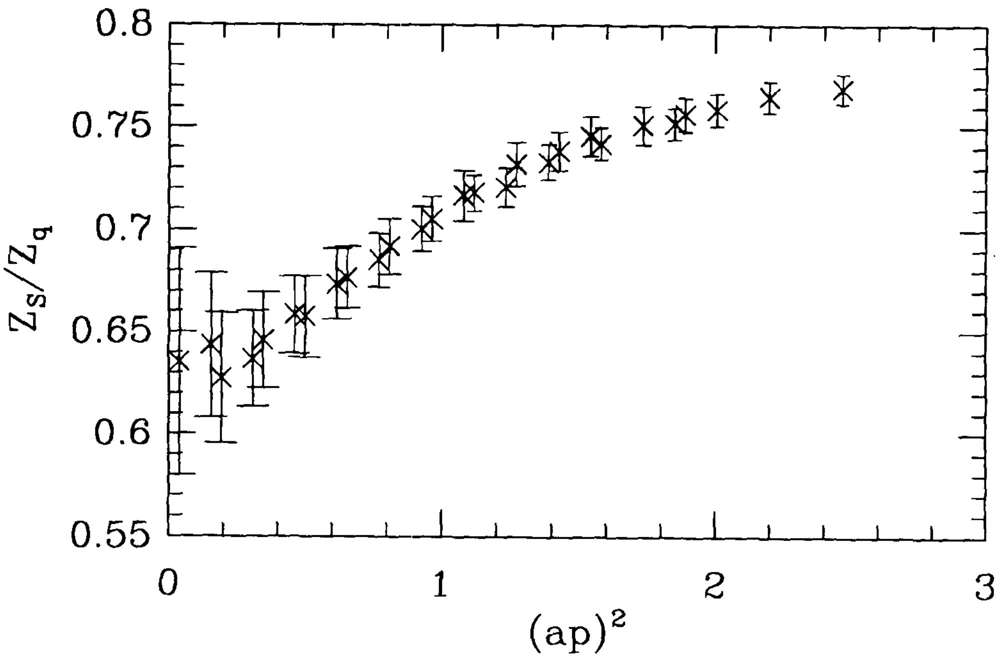


$$m_s^{\overline{\mathrm{MS}}}(\mu) \;=\; m_s\tilde{M}(2-\tilde{M})\left[1-\frac{2\alpha_s}{\pi}\left(\ln(\mu a)-C_m\right)\right]$$

Renormalization method of Martinelli *et al.*

Define a renormalized operator $O(\mu) = Z_O(\mu a)\, O(a)$ by imposing the regularization scheme independent condition

$$\frac{Z_O(\mu a)}{Z_q(\mu a)} \operatorname{Tr}\left[P_O \Lambda_O(pa)\right]\Big|_{p^2=\mu^2} = 1$$



Topics in the Physics of RHIC: Parity Violation in Hot QCD, Heavy Quarks, Spin, and Nuclear Collisions

Dmitri Kharzeev

Topics in the physics of RHIC:

Parity violation in hot QCD,

Heavy quarks, Spin, and Nuclear collisions

Dmitri Kharzeev

1. Introduction
2. Parity violation at RHIC?
3. Long-range forces of QCD
4. Measuring polarized glue in quarkonium production

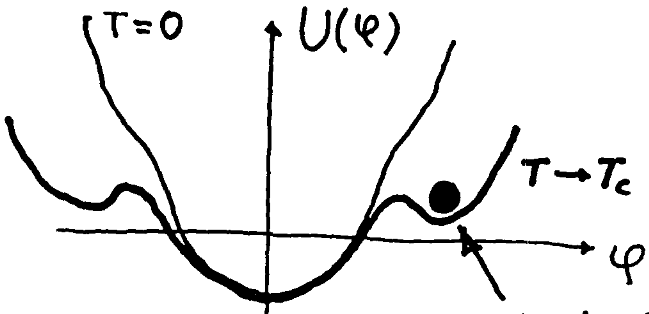
Parity violation in hot QCD

- Strong interactions are known to conserve P, CP. Can this change at high temperature/density?

D. K., R. Pisarski, M. Tytgat
Phys. Rev. Lett. 81 (98) 512

- Consider the vacuum of the non-linear σ-model

$$U(\varphi_i) = f_\pi^2 \left[- \sum_i \mu_i^2 \cos \varphi_i + \frac{a}{2} \left(\sum_i \varphi_i - \theta \right)^2 \right]$$



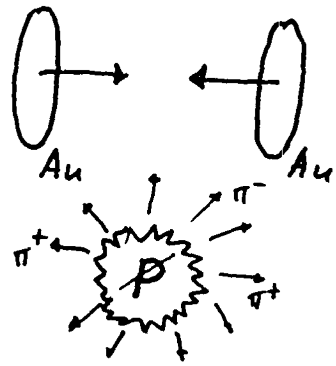
when $T \to T_c$, topological susceptibility $a \searrow$

metastable solution: P & CP odd "false" vacuum

- Experimental signatures:

initial state — P even

final state — P odd?



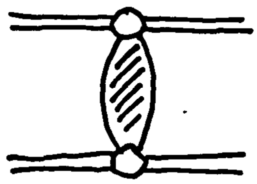
⇒ Measure global P-odd observables constructed from pion momenta on the EbyE basis

Long–range forces of QCD

H. Fujii, D.K.
hep-ph/9903495

- How to "derive" the nuclear force from QCD?

Consider the interaction of two small color dipoles (heavy quarkonia); use OPE (= multipole expansion), spectral representation



- Perturbation theory:

$$V^{pt}(R) = -\underbrace{g^4}_{\text{coupling}} \Big(\underbrace{d_2}_{\text{Wilson coeff}} \underbrace{\frac{a_0^2}{\epsilon_0}}_{\text{Bohr radius and energy}}\Big)^2 \cdot \frac{23}{8\pi^3} \cdot \frac{1}{R^7} \quad \sim (N_c^2 - 1)$$

but: fails at large R

- Use low energy theorems to perform matching at large distances:

$$\theta_\mu^\mu = -\partial_\mu \pi^a \partial^\mu \pi^a + \ldots \iff \theta_\mu^\mu = \frac{\beta(g)}{2g} G^{\mu\nu a} G^a_{\mu\nu}$$

$$\Rightarrow \quad V(R) \underset{R\to\infty}{=} -\left(d_2 \frac{a_0^2}{\epsilon_0}\right)^2 \left(\frac{4\pi^2}{b}\right)^2 \frac{3}{2} (2\mu)^4 \frac{\mu^{1/2}}{(4\pi R)^{5/2}} e^{-2\mu R}$$

- Sum rule:

$$\boxed{\int d^3R \left[V(R) - V^{pt}(R)\right] = -\left(d_2 \frac{a_0^2}{\epsilon_0}\right)^2 \cdot \left(\frac{4\pi^2}{b}\right)^2 \cdot 16\, \underbrace{|\epsilon_{vac}|}_{\text{energy density of QCD vacuum}}} \quad \sim \frac{N_c^2 - 1}{(11N_c - 2N_f)^2}$$

- Applications:

$\sigma_{el}(\pi\Psi) \lesssim 10^{-2}$ mb

$\sigma(\pi\Psi \to \pi\Psi') \lesssim 0.1$ mb

...

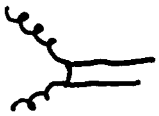
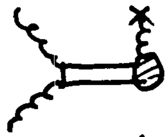
– needed to understand J/Ψ suppression

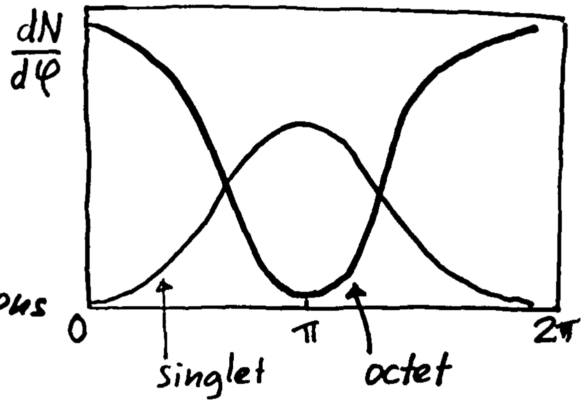
Polarized glue and quarkonium production

R.L. Jaffe, D.K.
hep-ph/9903280

- Can one use polarized pp beams at RHIC to constrain the mechanism of quarkonium production?
  Can asymmetries in quarkonium production be used to extract ΔG?
- Consider, for example, $pp \to \chi_2 + X$ process
  $\qquad\qquad\hookrightarrow J/\psi + \gamma$

  Color singlet and color octet models



  give very different predictions for the helicity of the χ_2 and, therefore, for the angular distributions
- This fact can be used to check the production mechanism and to measure ΔG:

$$\frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = - \frac{\Delta g(x_1, M^2)\,\Delta g(x_2, M^2)}{g(x_1, M^2)\, g(x_2, M^2)} \times \frac{\left(\frac{1}{2} + \frac{1}{2}\cos^2\theta\right) - \frac{A^8}{A^1}\left(\frac{3}{4} - \frac{1}{4}\cos^2\theta\right)}{\left(\frac{1}{2} + \frac{1}{2}\cos^2\theta\right) + \frac{A^8}{A^1}\left(\frac{3}{4} - \frac{1}{4}\cos^2\theta\right)}$$

Azimuthal Asymmetries at RHIC

Daniël Boer

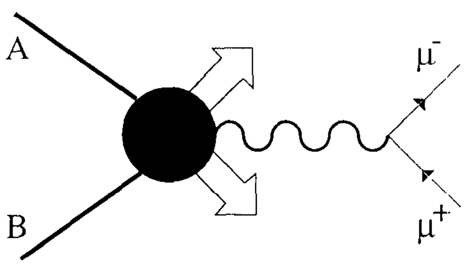
Azimuthal Asymmetries at RHIC

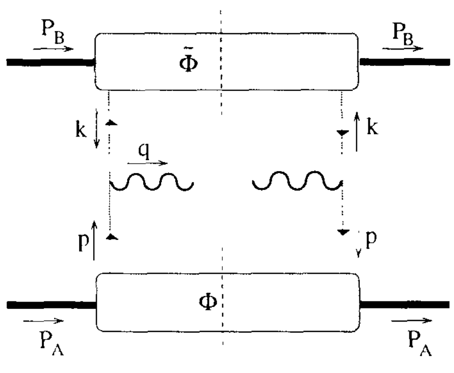
Daniël Boer

- Goal: To understand the spin structure of hadrons
- Means: Asymmetries in hard scattering processes

For example:
Large single spin asymmetries have been found in $p + p^{\uparrow} \rightarrow \pi + X$

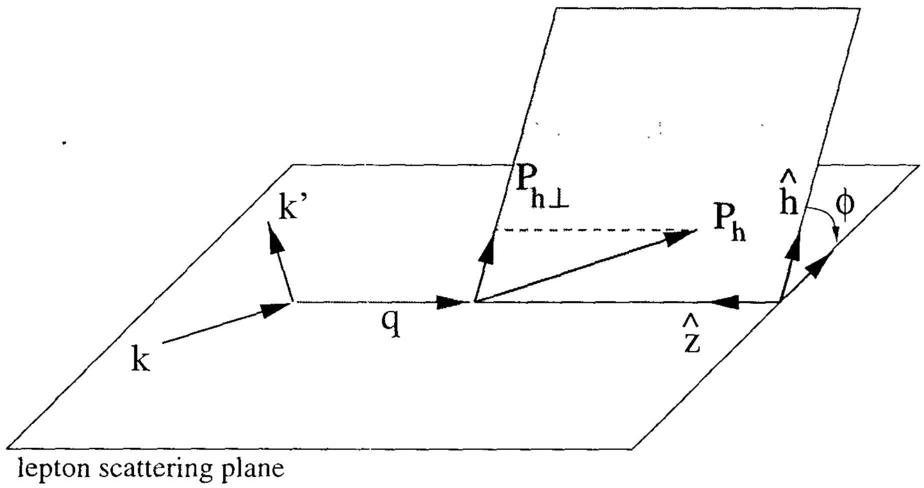
How to interpret such asymmetries?
Relevant for polarized proton-proton collisions at RHIC





HERMES Asymmetry in $e + \vec{p} \rightarrow e' + \pi + X$

HERMES reported a $\sin\phi$ asymmetry at DIS99 [Zeuthen, April '99]



$$
\begin{aligned}
\sigma_{OL} &\propto \sin\phi\left(\frac{M}{Q}h_L H_1^\perp + \frac{M}{Q}h_{1L}^\perp\left(H + \frac{z\boldsymbol{k}_T^2}{M_h^2}H_1^\perp\right)\right) \qquad \text{T-odd!} \\
\sigma_{OT} &\propto \sin\phi\, h_1 H_1^\perp + \ldots
\end{aligned}
$$

Involve transverse momentum dependent functions. For example:

$H_1^\perp(z, k_T)$ [Collins effect]

$$\text{Prob}\,[q(|\boldsymbol{k}_T \times \boldsymbol{s}_T|) \rightarrow \pi X] \neq \text{Prob}\,[q(-|\boldsymbol{k}_T \times \boldsymbol{s}_T|) \rightarrow \pi X]$$

Theoretical Issues

Theoretically one wants to describe the asymmetries in terms of universal quantities: parton densities.

Questions: What are they? Where do they show up? ...

(1) Proof of factorization (leading twist $\surd$, subleading twist?)

$$\frac{d\sigma}{dx\,d\bar{x}\,d\boldsymbol{q}_T} \propto \int d^2\boldsymbol{p}_T\,d^2\boldsymbol{k}_T\,q(x,\boldsymbol{p}_T)\,\overline{q}(\bar{x},\boldsymbol{k}_T)\,H(x,\bar{x},\boldsymbol{p}_T,\boldsymbol{k}_T,\boldsymbol{q}_T)$$

Next-to-leading twist is relevant [recent HERMES result]

(2) Proper definition of $q(x,k_T)$, $\Delta q(x,k_T)$, ...

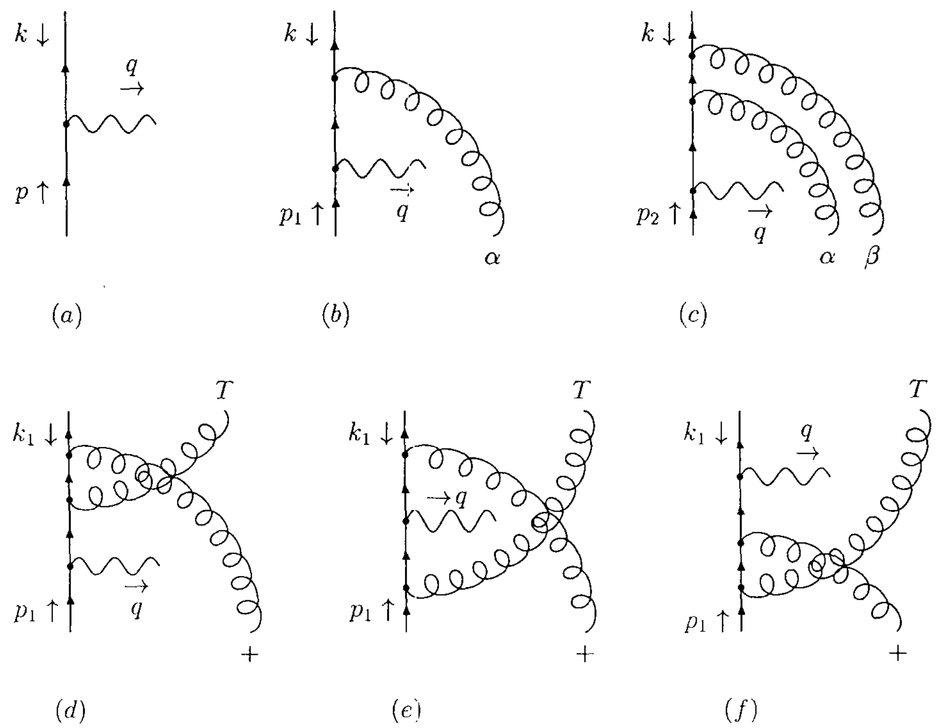
(3) Evolution equations

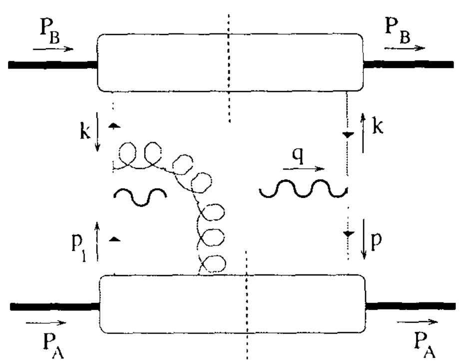
(4) Expressing cross sections/asymmetries in terms of the functions

(5) Estimating asymmetries

Together with P.J. Mulders, A.A. Henneman (Amsterdam), R. Jakob (Pavia) work is currently in progress on several of these points.

Color Gauge Invariance





D.B. & P.J. Mulders
in preparation

→ path-ordered exponentials in off-lightcone non-local operators

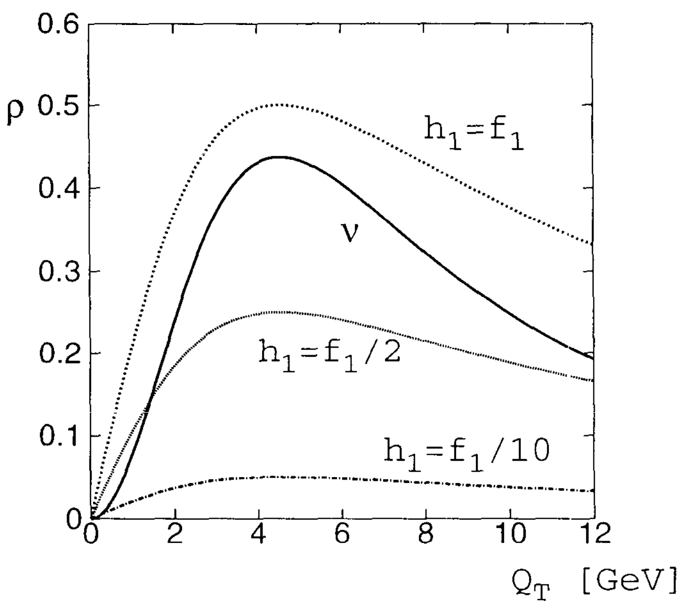
Azimuthal Asymmetries at RHIC

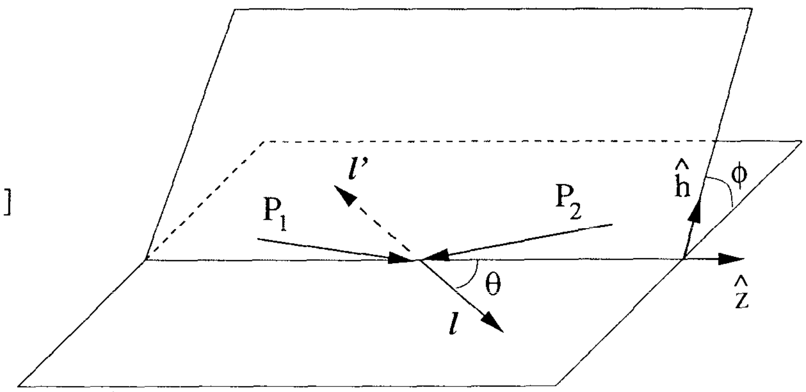
D.B., hep-ph/9902255 (to appear in Phys. Rev. D);
hep-ph/9905336 (to appear in Nucl. Phys. B (Proc. Suppl.))

The polarized Drell-Yan process cross section:

$$\frac{d\sigma}{d\Omega\, d\phi_S} \propto 1+\cos^2\theta+\sin^2\theta\left[\frac{\nu}{2}\cos 2\phi - \rho\,|\boldsymbol{S}_T|\sin(\phi+\phi_S)\right]+\ldots$$

Relation for the case of one flavor: $\rho = \frac{1}{2}\sqrt{\frac{\nu}{\nu_{\text{max}}}}\,\frac{h_1}{f_1}$





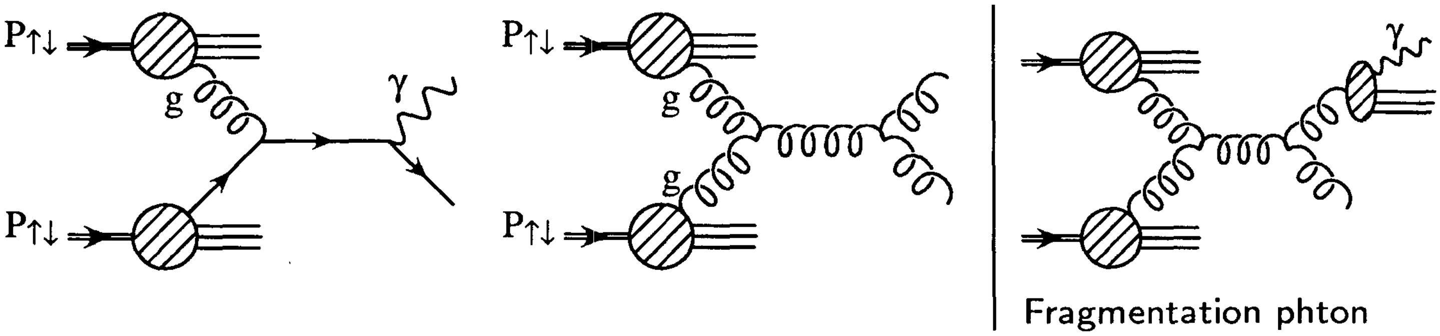
One-loop Calculation of 5 Gluon Amplitudes in the Background Field Gauge

Yoshiaki Yasui

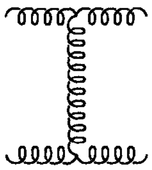
[1] Motivations

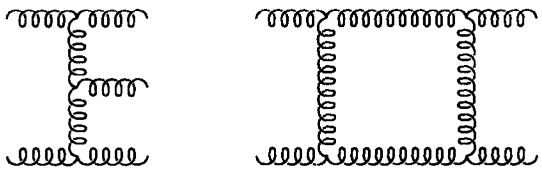
Spin Physics at RHIC ($\Delta g, J/\Psi, Jets, \cdots$)

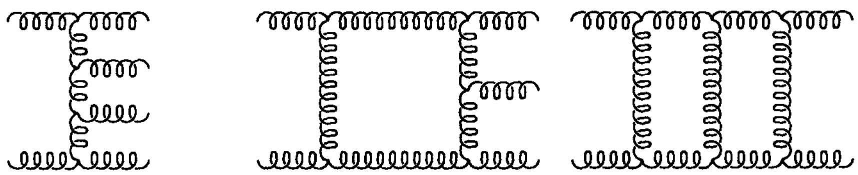
(Ex.) Measurement of the gluon component



$\Rightarrow$ Jets analysis is very important!! But, $\cdots$

LO  $\cdots$

NLO  $\cdots$

NNLO  $\cdots$

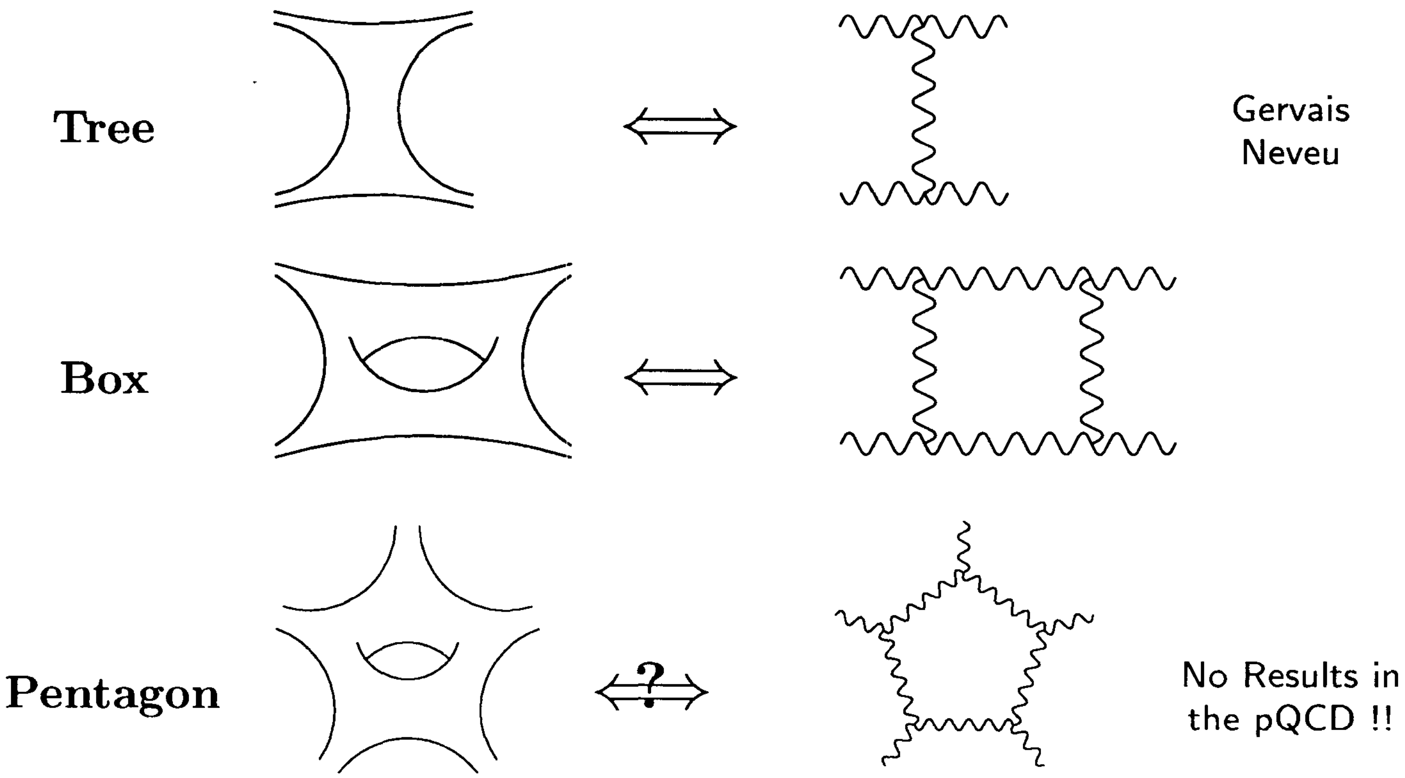
We have to calculate not only LO but also NLO and NNLO.

Theoretical Issue

String Amplitudes $\Longrightarrow$ QCD Amplitudes

Z.Bern, L. Dixon and D. Kosower

(String Tension $\longrightarrow \infty$)



$\Rightarrow$ Calculation of 5 gluon amplitudes in the pQCD?

[2] Why Background Field Gauge

Gauge Invariance

Lagrangian: $\quad \mathcal{L}(A_\mu) \longrightarrow \mathcal{L}(Q_\mu + B_\mu)$

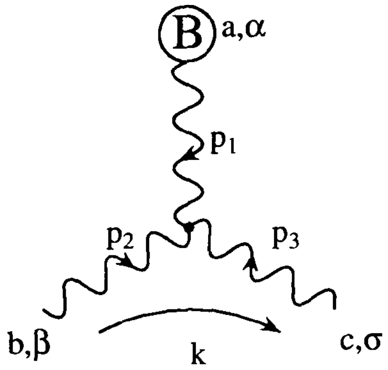
Gauge Fixing Condition: $\quad (\partial_\mu \, \delta^{ac} + g f^{abc} B^b_\mu) \; Q^{c\mu} = 0$

$\Rightarrow$ Gauge Invariant Effective Action

$$\Gamma(Q = 0, B)_{\text{effective}} = \Gamma(B)_{\text{effective}}$$

L.F.Abbott

Simple Feynman Rule ($\xi = 1$)



$$g f^{abc} [\; (p_2 - p_3)_\alpha \;\; g_{\beta\sigma} + 2 p_{1\sigma} g_{\alpha\beta} - 2 p_{1\beta} g_{\alpha\sigma}]$$

$$\Downarrow$$

k: Integral Momenta $\cdots \int d^D k$

$\Longleftrightarrow$ Covariant Gauge

$$g f^{abc} [(p_2 - p_3)_\alpha g_{\beta\sigma} + (p_3 - p_1)_\beta g_{\alpha\sigma} + (p_1 - p_2)_\sigma g_{\alpha\beta} \;]$$

$\Rightarrow$ BG simplifies Loop Calculations !!

[3] One loop Results

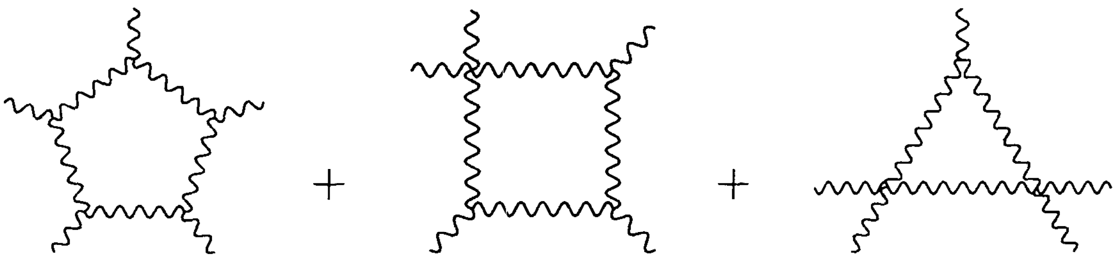
Polarized PP $\Longrightarrow$ Helicity Amplitude (S. Parke et.al.)

$$\varepsilon^{\pm}(p,k)_\mu = f_N \overline{u}_{\pm}(p)\gamma_\mu v_{\pm}(k) \;\; \Rightarrow \;\; \pm \frac{\langle p^{\pm}|\gamma_\mu|k^{\pm}\rangle}{\sqrt{2}\langle k^{\mp}|p^{\pm}\rangle}$$

$$\langle q^{\pm}| \equiv \frac{1}{2}\overline{u}(q)(1\mp\gamma_5), \qquad |\bar{q}^{\pm}\rangle \equiv \frac{1}{2}(1\pm\gamma_5)v(\bar{q})$$

p $\cdots$ the gauge boson momentum $\qquad$ k $\cdots$ the reference momentum

1PI amplitudes $\propto Tr(T^aT^bT^cT^dT^e)$



$$A^{1-loop}_{(+,+,+,+,+)} = -\frac{i}{(4\pi)^2}\frac{F(a1,a2,a3,a4,a5)}{\langle 21\rangle\langle 32\rangle\langle 43\rangle\langle 54\rangle\langle 15\rangle} + \text{(Cyclic Permutation)}$$

where $\langle ij\rangle = \langle i^-|j^+\rangle$ $\qquad$ $a1 = \sqrt{-\frac{S_{23}S_{34}}{S_{45}S_{51}S_{12}}}, \cdots$

[4] Summary

Spin Physic at RHIC

Analysis of Jets production is very important.

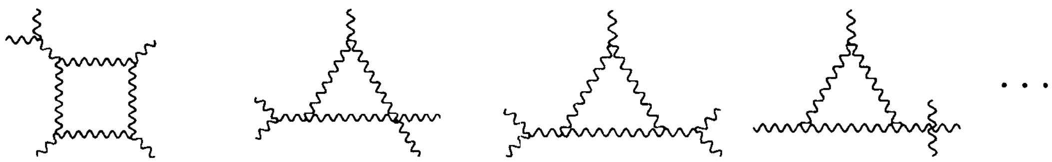
$\Rightarrow$ Bern.et.al. calculated 5 gluon amplitudes in the one-loop level with using the string theory.

$\Rightarrow$ No one have done it in the orthodox pQCD.

$\Rightarrow$ I demonstrated the one-loop calculation of the 5 gluon amplitudes in the framework of the pQCD

"Background Field Gauge" $\Longrightarrow$ Very Powerful!!

Next Step $\Longrightarrow$ 1PR Parts



MAPLE OUTPUT

$$F(a1, a2, a3, a4, a5) := -4\,\frac{I\ln(a1)\,LEV_{1,2,3,4}\,(-a1^2 + a2\,a5)}{(a1 - a2)\,(-a1 + a5)} + \frac{1}{6}\ln(a1)\,(-11\,a5^2\,a4\,a3^2\,a1^2$$
$$- 44\,a2^2\,a5^2\,a3^2\,a1 + 6\,a3\,a1^5\,a4 - 44\,a3^2\,a1^3\,a5^2 - 55\,a4^2\,a2\,a1^3\,a3 + 19\,a5\,a3^2\,a1^3\,a4$$
$$+ 23\,a2^2\,a4^2\,a3\,a1^2 + 5\,a5^2\,a4^2\,a2^2\,a3 + 11\,a5^2\,a1^2\,a4^2\,a3 - 22\,a4^2\,a2\,a1^4 - 22\,a2^3\,a1^2\,a4^2$$
$$+ 22\,a3^2\,a1^2\,a5^3 - 19\,a5^2\,a1\,a4^2\,a3\,a2 + 40\,a5^3\,a3\,a4\,a1\,a2 - 87\,a3\,a5^2\,a1^2\,a4\,a2$$
$$- 28\,a3\,a5\,a1\,a2^2\,a4^2 + 54\,a3\,a5^2\,a4\,a2^2\,a1 + 29\,a4^2\,a3\,a1^4 + 74\,a3\,a2\,a4^2\,a5\,a1^2$$
$$- 22\,a5^2\,a2^3\,a4^2 + 22\,a3^2\,a1^2\,a2^2\,a5 + 7\,a1\,a4\,a5\,a3^2\,a2^2 - 5\,a3^2\,a1^4\,a4 - 4\,a1\,a4\,a5\,a3\,a2^3$$
$$- 33\,a1^2\,a4\,a5\,a3\,a2^2 + 60\,a3\,a1^3\,a4\,a2\,a5 + 22\,a2^2\,a5^3\,a3^2 - 26\,a5\,a3^2\,a1^2\,a4\,a2$$
$$+ 44\,a4^2\,a2^2\,a1^3 + 16\,a2\,a5^2\,a3^2\,a1\,a4 + 22\,a3^2\,a5\,a1^4 - 29\,a5^3\,a3\,a4\,a2^2 - 5\,a2^2\,a5^2\,a3^2\,a4$$
$$- 44\,a2\,a5^3\,a3^2\,a1 + 88\,a2\,a5^2\,a3^2\,a1^2 + 5\,a3\,a4\,a2^3\,a5^2 + 28\,a3\,a5^2\,a4\,a1^3 - 40\,a3\,a5\,a1^3\,a4^2$$
$$- 23\,a3\,a1^4\,a4\,a5 - 11\,a5^3\,a3\,a4\,a1^2 + 44\,a1\,a4^2\,a2^3\,a5 + 8\,a3\,a1^3\,a4\,a2^2 - a3\,a1^2\,a4\,a2^3$$
$$- 13\,a3\,a2\,a1^4\,a4 + a3^2\,a4\,a2^2\,a1^2 + 4\,a3^2\,a2\,a1^3\,a4 - 44\,a3^2\,a2\,a1^3\,a5 - 22\,a5^2\,a4^2\,a2\,a1^2$$
$$+ 44\,a5\,a1^3\,a4^2\,a2 + 44\,a5^2\,a4^2\,a2^2\,a1 - 88\,a5\,a1^2\,a4^2\,a2^2)\,\big/\,($$
$$a2\,a1\,a5\,(a1 - a2)^2\,a3^2\,(-a1 + a5)^2\,a4^2)$$

>

$$LEV_{1,2,3,4} = 4\,i\,\varepsilon_{\mu,\nu,\rho,\sigma}\,p_1^{\mu}\,p_2^{\nu}\,p_3^{\rho}\,p_4^{\sigma}$$

>

Calculation of 5 gluon amplitudes in the background field gauge

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Brookhaven National Laboratory
Upton, NY, 11973, USA

Abstract

RHIC Spin Physics program will provide us fruitful information on the proton spin structure. For example, the gluon component of the polarized proton will be investigated by measuring the processes $PP \to \gamma + X$ ($gq \to \gamma q$) and $PP \to Jets + X$ ($gg \to gg, qq, \cdots$). The gluon component has the essential role for the proton spin structure function g_1 concerning with the spin crisis problem. To analyze the spin structure of the proton, we can easily imagine that perturbative calculations for the processes of jets production are indispensable. And for these processes, not only Leading Order but also Next to Leading and Next to Next to Leading Order contributions are sizable. We can not ignore these higher order corrections. Unfortunately higher order calculations usually induce uncontrollable numbers of terms and diagrams. Thus, orthodox methods become useless soon.

By the way, recently, we have seen much progress in methods of perturbative calculations. Bern, Dixon and Kosower intruduced a new formulation, using a string-

based technique, to compute the one-loop amplitudes in QCD. They demonstrated the calculation of 4 and 5 gluon amplitudes in the one loop level. On the other hand, no one has done the one loop calculation of the 5 gluon amplitudes in the orthodox field theory. And the relation between the string-based technique and the orthodox perturbative calculations are not clear, yet.

In this work, I try to calculate 5 gluon amplitudes without using the string based methods. Of course, orthodox methods, like a covariant gauge, are useless. Here I use the background field gauge, the helicity method and so on. The background field gauge gives gauge invariant off-shell 1PI Green's functions. In addition, Feynman Rules of this gauge have very simple structures. It simplifies calculations of gluon loop diagrams.

This time, I will show the result of 1PI part. It is a part of the full amplitude, but by using the background field gauge, the 1PI part itself becomes gauge invariant. Of course, to obtain the complete result, we have to calculate the 1PR part. I am sure that I can also calculate 1PR parts in the straightforward way.

Parity Violation Through Color Superconductivity

Dirk Rischke

Parity Violation Through Color-Superconductivity

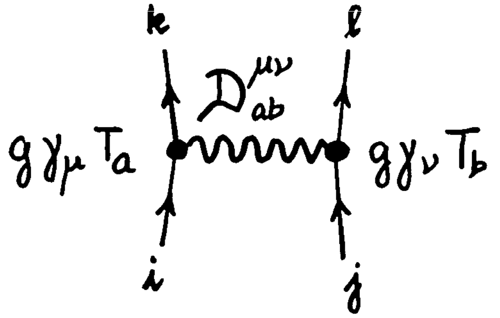
R.D. Pisarski[1], D.H. Rischke[2]

[1] Physics Dept., Brookhaven National Laboratory

[2] RIKEN-BNL Research Center, Brookhaven National Lab

QCD at high baryon densities:

qq scattering amplitude



$$\sim -\tfrac{1}{3}(\delta_{ki}\delta_{\ell j} - \delta_{kj}\delta_{\ell i}) + \tfrac{1}{6}(\delta_{ki}\delta_{\ell j} + \delta_{kj}\delta_{\ell i})$$

$[\bar{3}]^c_a$! $\qquad$ $[6]^c_s$

$\Rightarrow$ One-gluon exchange is attractive in $[\bar{3}]^c_a$-channel!

$\Rightarrow$ Condensation of quark (Cooper) pairs at sufficiently high densities and sufficiently low temperatures!

$$\Delta^{ij}_{fg\alpha\beta} \equiv \langle \psi^i_{f\alpha} \psi^j_{g\beta} \rangle \neq 0$$

$i,j = 1,\ldots,N_c$ (=3
$f,g = 1,\ldots,N_f$
$\alpha,\beta = 1,\ldots,4$

$m = 0$, $J = 0$: $\qquad \boxed{\Delta^{ij} = -\Delta^{ji} \;,\quad \Delta_{fg} = -\Delta_{gf}}$

(i) $\Rightarrow$ $N_f = 2$: $\quad \Delta^{ij}_{fg} = \epsilon_{fg}\,\epsilon^{ijk}\,\Delta^k \;,\quad \Delta^k \sim \delta^{k\bar{b}}$

$\Rightarrow$ r and g condense to $\bar{b}$, b do not condense!

(ii) $\Rightarrow$ $N_f = 3$: $\quad \Delta^{ij}_{fg} = \epsilon_{fgh}\,\epsilon^{ijk}\,\Delta^k_h \;,\quad \Delta^k_h \sim \delta^k_h$

$\Rightarrow$ color-flavor locking! $\quad$ M. Alford, K. Rajagopal, F. Wilczek, NPB 537 (99) 443

$(ud)^{\bar{b}}$, $(us)^{\bar{g}}$, $(ds)^{\bar{r}}$

$m=0,\ J=0$:

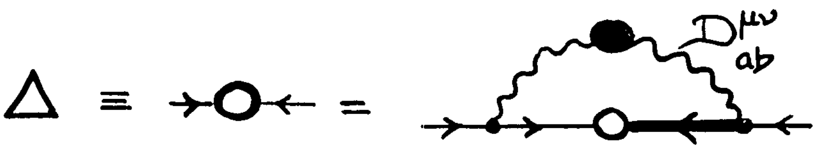
K.V. Pisarski, D.H. Rischke, nucl-th/9903043

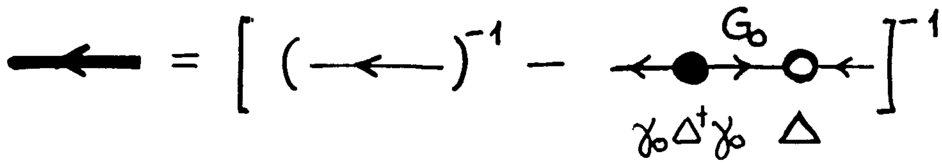
$$\Delta = \phi^+_{r+}\mathcal{P}^+_{r+} + \phi^+_{\ell-}\mathcal{P}^+_{\ell-} + \phi^-_{r-}\mathcal{P}^-_{r-} + \phi^-_{\ell+}\mathcal{P}^-_{\ell+}$$

where $\mathcal{P}^+_{\substack{r+\\ \ell-}} = \dfrac{1\pm\gamma_5}{2}\,\dfrac{1\pm\gamma_5\gamma_0\vec{\gamma}\cdot\hat{k}}{2}$, $\mathcal{P}^-_{\substack{r-\\ \ell+}} = \dfrac{1\pm\gamma_5}{2}\,\dfrac{1\mp\gamma_5\gamma_0\vec{\gamma}\cdot\hat{k}}{2}$

$\Rightarrow$ only particles with the same chirality and helicity condense

Gap equation: $N_f=2,\ J=0,\ m=0$:

$\Delta \equiv$ 

$G \equiv$ 

$$\Rightarrow\quad \phi \sim \mu\, e^{-6\pi/g} \quad (\text{vs. } \mu\, e^{-a/g^2} \text{ in BCS theory})$$

due to dynamical screening of transverse gluons

cf. D.T. Son, hep-ph/9812287:

$$\phi \sim \mu\, e^{-3\pi^2/\sqrt{2}\,g}$$

$$\Rightarrow\quad \phi^+_{r+} = e^{i\varphi}\phi^+_{\ell-}\,,\quad \phi^-_{r-} = e^{i\varphi}\phi^-_{\ell+}\,,$$

φ undetermined by gap eqs., but fixed through condensation!

$\Rightarrow$ spontaneous breaking of $U_A(1)$-symmetry!

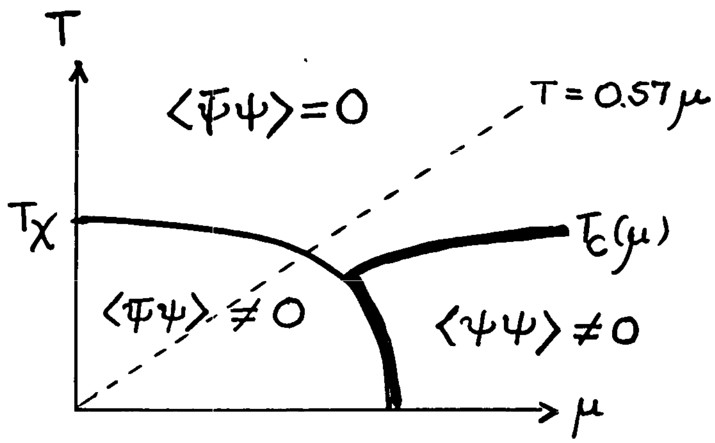
$\varphi = \pi$: condensation in $J^P = 0^+$-channel
$\varphi = 0$: —— " —— $J^P = 0^-$-channel

$\Rightarrow$ **Parity violation!** R.D. Pisarski, D.H. Rischke, nucl-th/981110

Where does color-superconductivity occur?

$$T_C \simeq 0.57\, |\phi(T=0)| \quad , \qquad \phi(T=0) \sim \mu$$

M. Alford, K. Rajagopal, F. Wilczek, PLB 422 (98) 247 ;
R. Rapp, T. Schäfer, E.V. Shuryak, M. Velkovsky, PRL 81 (98) 53



⇒ High density, (relatively) low temperature

⇒ Fragmentation region at RHIC energies !!?

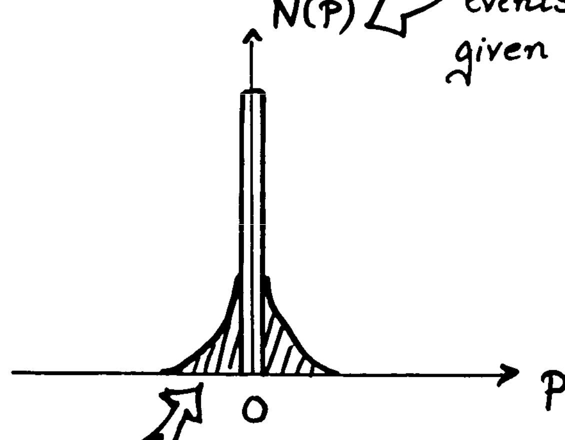
How to observe color-superconductivity?

Through parity violation!

e.g.: $\mathcal{P} \equiv \sum_{(\pi^+,\pi^-)} (\hat{p}_{\pi^+} \times \hat{p}_{\pi^-}) \cdot \hat{z}$

(π^+,π^-) - pairs in a given event

no. of events w given $\mathcal{P}$



Signal for parity violation

The Chiral Phase Transition in Flavor SU(3) and Possible Signals for RHIC

Jürgen Schaffner-Bielich

The Chiral Phase Transition in Flavor SU(3) and Possible Signals for RHIC

Jürgen Schaffner-Bielich

Partial Restoration of Chiral $U_A(1)$ Symmetry seen just above T_c by QCD lattice calculations

δ: 0^+, $I=1$

$$\frac{m_\delta(T) - m_\pi(T)}{m_\delta - m_\pi} \lesssim (5\text{-}15)\,\% \qquad a_0(980)$$

change by one order of maguitude

Chandrasekharan et al., PRL 82, 2463 (1999)
Chen et al., hep-lat/9812011

$\Rightarrow$ Signal at RHIC ?

Explore consequences with SU(3) chiral Lagrang

$$\mathcal{L} = \partial_\mu \phi^+ \partial^\mu \phi + \tfrac{1}{2}\mu^2\, Tr\, \phi^+\phi^+ - \lambda Tr(\phi^+\phi)^2 - \lambda'(Tr\,\phi^+\phi)^2$$
$$+ \underbrace{c}_{\text{breaks } U_A(1)} \cdot (\det\phi + \det\phi^+) + \varepsilon \cdot \underbrace{\sigma}_{\text{"}u\bar u + d\bar d\text{"}} + \varepsilon' \cdot \underbrace{\zeta}_{\text{"}s\bar s\text{"}}$$

effective restoration of chiral SU(3):

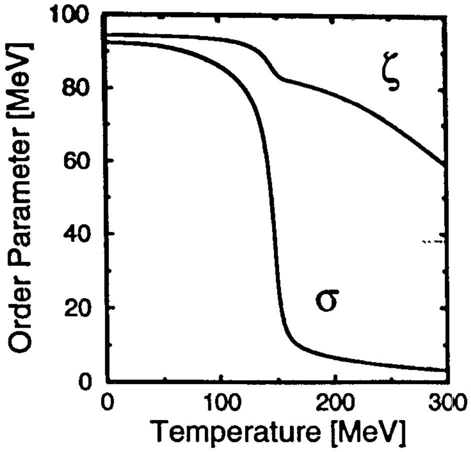
$$m_\pi = m_\sigma < m_{a_0} = m_\eta \qquad \Delta m \sim c\cdot\zeta$$

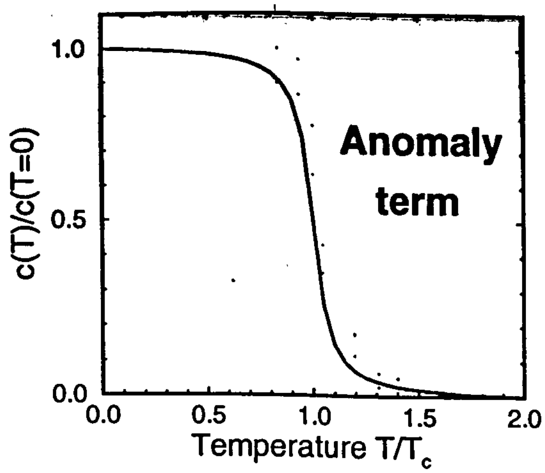
effective restoration of $U_A(1)$:

$$m_\pi = m_\sigma \approx m_{a_0} = m_\eta \qquad (c \approx 0)$$

nonstrange

Order parameters: put in "by hand":





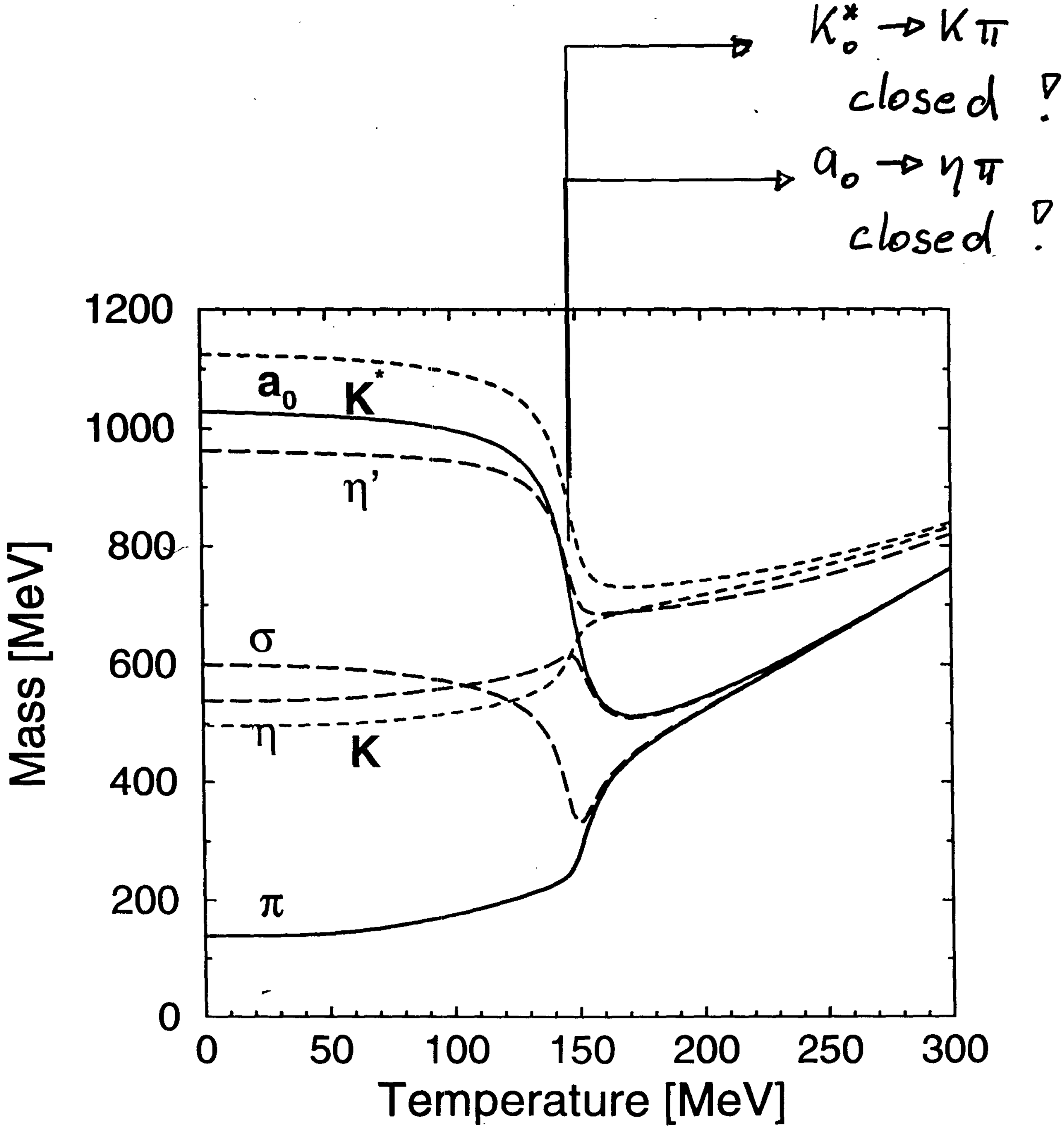
Prediction 1: η's enhanced up to four times!

$a_0(980)$, $T = 50$-100 MeV, m_{a_0} decreases with T!
as $m_{a_0} \to m_\eta$, $a_0 \to \eta + \pi$ blocked by phase space (below T_c)!

$\mathcal{M}(a_0 \to \eta_{NS} + \pi) = 4\lambda\sigma \approx \sigma$ in χ SU(3) phase

$\mathcal{M}(a_0 \to \eta_S + \pi) = 2c \approx \sigma$ in χ $U_A(1)$ phase

↪ inelastic channels are closed
elastic channels still large: $\mathcal{M}(a_0 a_0 \leftrightarrow \eta\eta) \sim \lambda$
$a_0 \not\to \pi\pi$ forbidden by isospin
$K\bar{K} \to a_0$ favoured as $m_{a_0} \ll 2m_K$
$\Rightarrow$ $N_{a_0^{0,+,-}} = N_\eta$ in χ phase
survives, if expansion from T_c to freeze-out T_f is sufficiently fast $\Delta\tau \leq \tau_{a_0} \approx 2$-$4$ fm



K₀* → Kπ closed !
a₀ → ηπ closed !
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
Mass [MeV]
Temperature [MeV]
a₀
K*
η'
σ
η
K
π

Prediction 2: scalar K (K_0^*) appears in $K\pi$ mass spectra ?

πK scattering: broad $K(900)$: 0^+, $I = 1/2$

Ishida et al., Prog. Theor. Phys. 98, 621 (1997)
Black et al., PRD 58, 054012 (1998)
Oller et al., PRD 59, 074001 (1999)

$m_{K_0^*}$ decreases with temperature, $\Delta m_K \sim c \cdot \sigma$

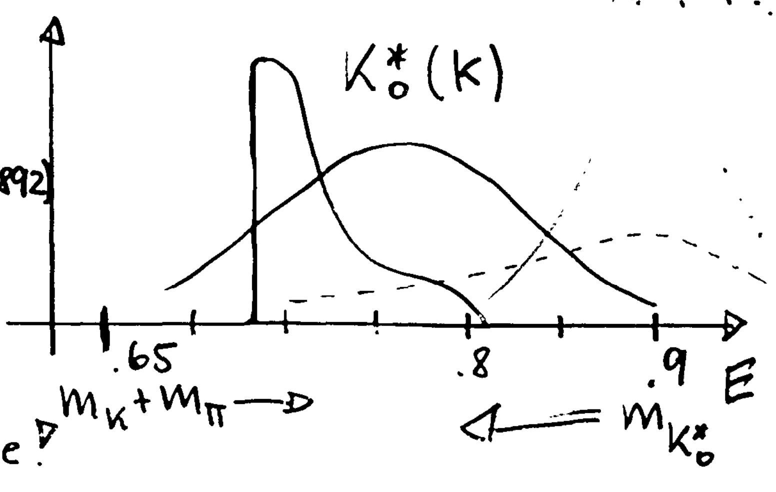
$\mathcal{M}(K_0^* \to K+\pi) = 2c + 4\lambda\zeta$, $\Gamma \approx .8\,\mathrm{GeV}$, $\Gamma_{c=0} \lessapprox .2\,\mathrm{GeV}$

smaller width for χ $U_A(1)$ phase ($c=0$)

as $m_{K_0^*} \to m_K$, $K_0^* \to K+\pi$ blocked by phase space (below T_c)?

system freezes out around T_c:

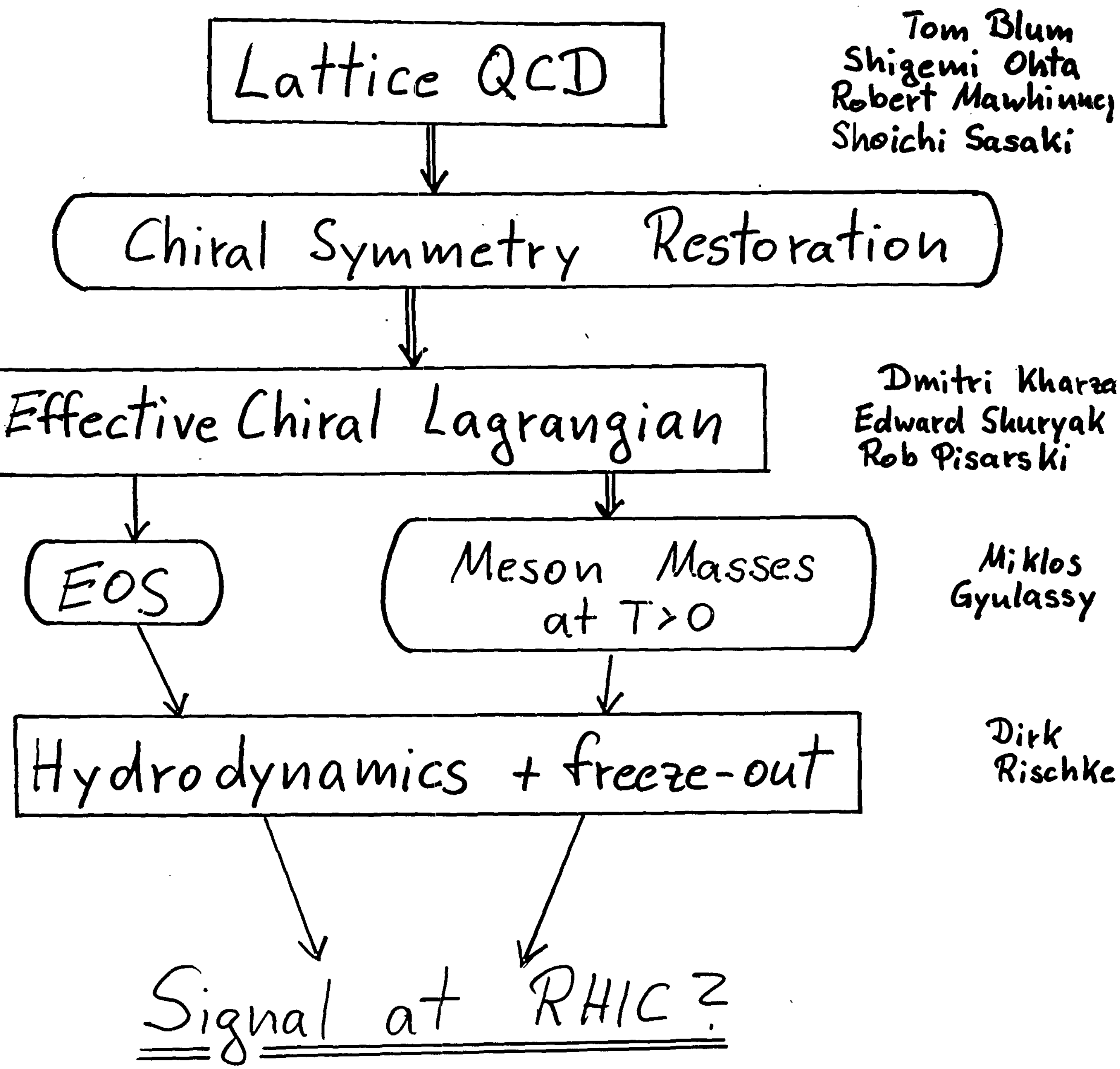
cusp structure appears in $K\pi$ mass spectra between $m_K + m_\pi = .64$ GeV and $m_K = .9$ GeV



background from vector $K^*(892)$

$\Gamma' = 50$ MeV ?

$N_{K_0^*} \approx N_K > N_{K^*(892)}$
as $m_{K_0^*} \approx m_K$ in χ phase?


Lattice QCD
Tom Blum
Shigemi Ohta
Robert Mawhinne
Shoichi Sasaki
Chiral Symmetry Restoration
Effective Chiral Lagrangian
Dmitri Kharze
Edward Shuryak
Rob Pisarski
EOS
Meson Masses at T>0
Miklos Gyulassy
Hydrodynamics + freeze-out
Dirk Rischke
Signal at RHIC?

QCDSP Project

Robert Mawhinney

RBRC Scientific Review

May 27-28, 1999

Lattice Physics and QCDSP Computers

- Columbia University:

  0.4 Teraflops
  8,192 processors
  Funded by DOE (including R/D)

- RIKEN/BNL

  0.6 Teraflops
  12,288 processors
  Funded by RIKEN (machine)
  Supported by BNL (DOE) through staff,
  space, ...

- RIKEN/BNL/Columbia collaboration

  - working on common interests using QCDSP at RIKEN/BNL
  - about 15 members
  - Monthly collaboration meetings

July 1997	First parts ordered
December 1997	First RIKEN-BNL motherboards
January 1998	Water and racks arrive at BNL.
March 1998	Production motherboards at BNL.
April 1998	Columbia 0.4 Tflops machine online
May 1998	First 100 Gflops of RIKEN-BNL QCDSP online
July 1998	0.5 Tflops of RIKEN-BNL QCDSP on-line
October 1998	Assembly complete. 450 Gflops on-line
December 1998	The hadronic/weak matrix calculation starts
January 1999	New version of QCDSP OS

RIKEN/BNL/Columbia QCD Project

- Systematic study of DWF formulation for quenched and unquenched QCD. (mostly complete)

- DWF full QCD thermodynamics

  Full continuum symmetries at finite a.
  Does this change the critical region?
  What happens in plasma?

- [illegible]

  Full symmetry group helps enormously in measuring $\mathcal{H}_{weak}$ operators.

  Better scaling than other formulations.

- Full QCD with staggered fermions, $N_f = 2, 4$

  What are visible effects of fermion loops?

Current machine configuration

Full QCD DWF thermodynamics

4 × 25 Gflops CU
3 × 50 Gflops CU
1 × 12 Gflops CU
4 × 6 Gflops CU
2 × 25 Gflops RIKEN/BNL

Quenched DWF T=0 physics

3 × 100 Gflops RIKEN/BNL

Full QCD, T=0 staggered fermions

1 × 150 Gflops CU
1 × 150 Gflops RIKEN/BNL
12 × 100 Gflops RIKEN/BNL

Code development, trial running
8 × 3 Gflops CU, RIKEN/BNL

Collaborators

Columbia University:

Ping Chen	Current students
Norman Christ	
George Fleming	
Adrian Kaehler	
Catalin Malureanu	
Tim Klassen	Columbia Postdoc starting 9/98
Robert Mawhinney	
Gabi Siegert	Postdoc supported by Max Kade Foundation
Chengzhong Sui	
Pavlos Vranas	Former Columbia Postdoc, now at UIUC
Lingling Wu	
Yuri Zhestkov	
Chulwoo Jung	Former students
Yubing Luo	

QCDSP Computer and staggered fermion physics:

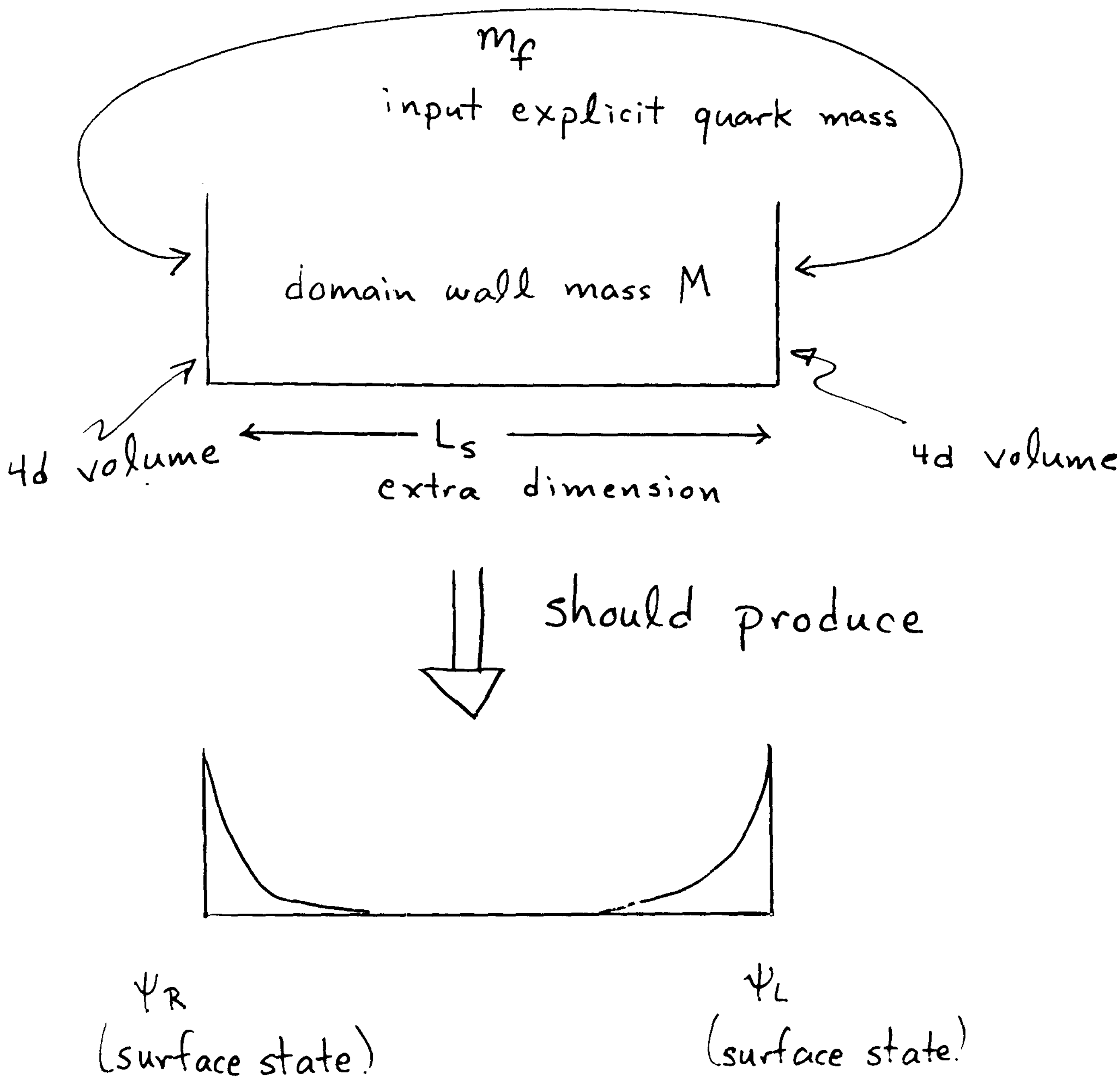
Alan Gara and John Parsons - Columbia University Nevis Laboratory
Igor Arsenin, Dong Chen, Robert Edwards (SCRI), Tony Kennedy (~~SCRI~~ Edinburgh),
Sten Hanson (FNAL), Greg Kilcup (OSU), Jim Sexton (Dublin)

RIKEN-BNL Research Center:

Tom Blum, Shoichi Sasaki, Matthew Wingate, Shigemi Ohta (KEK)

BNL:

Mike Creutz, Chris Dawson, Amarjit Soni



m_f - explicit mass, mixes chiralities

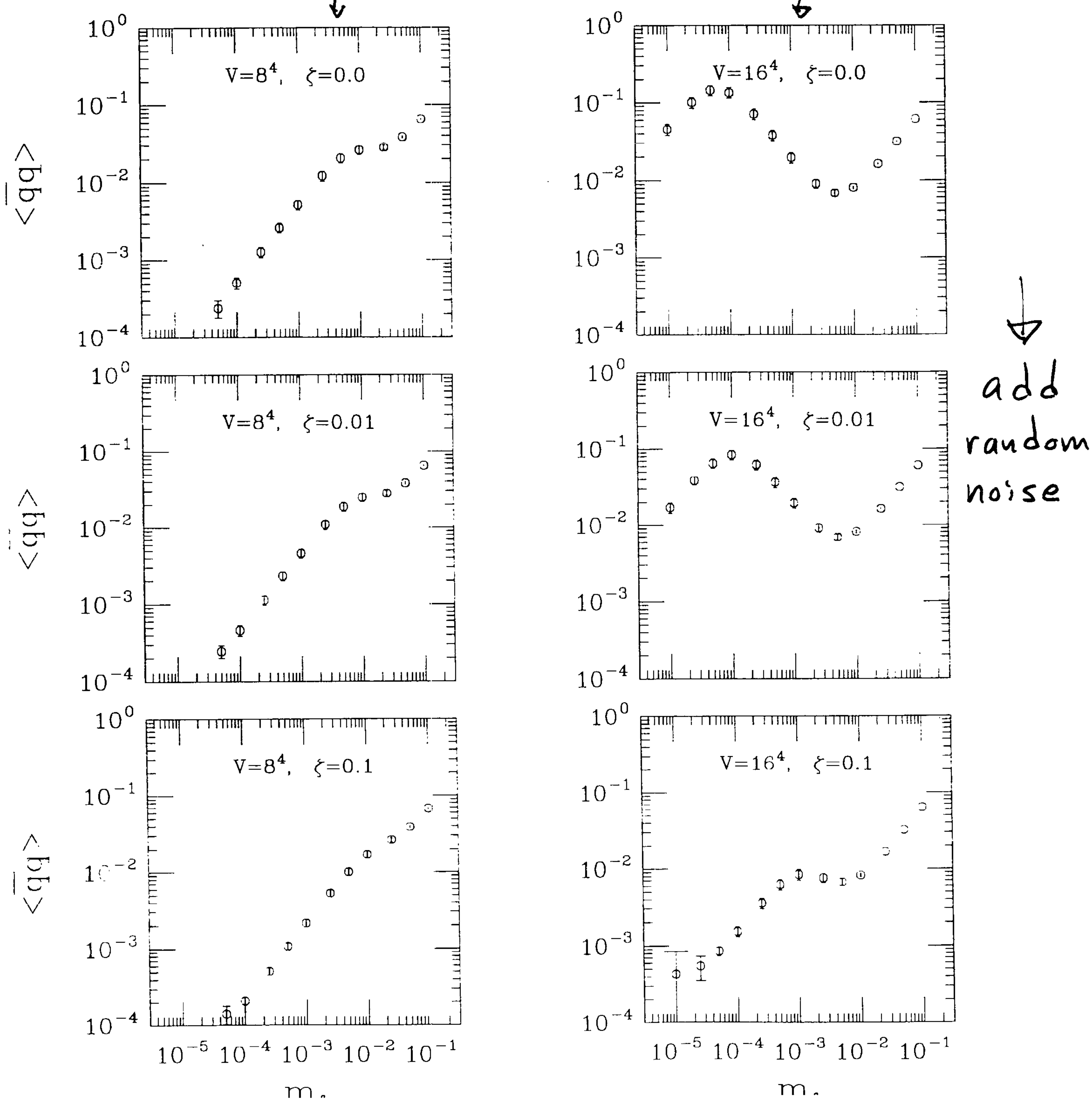
L_s - implicit mixing of chiralities

M - controls formation of surface states, normalization, level crossings.

Staggered fermions - smooth instanton configuration.

ρ/a small

ρ/a large

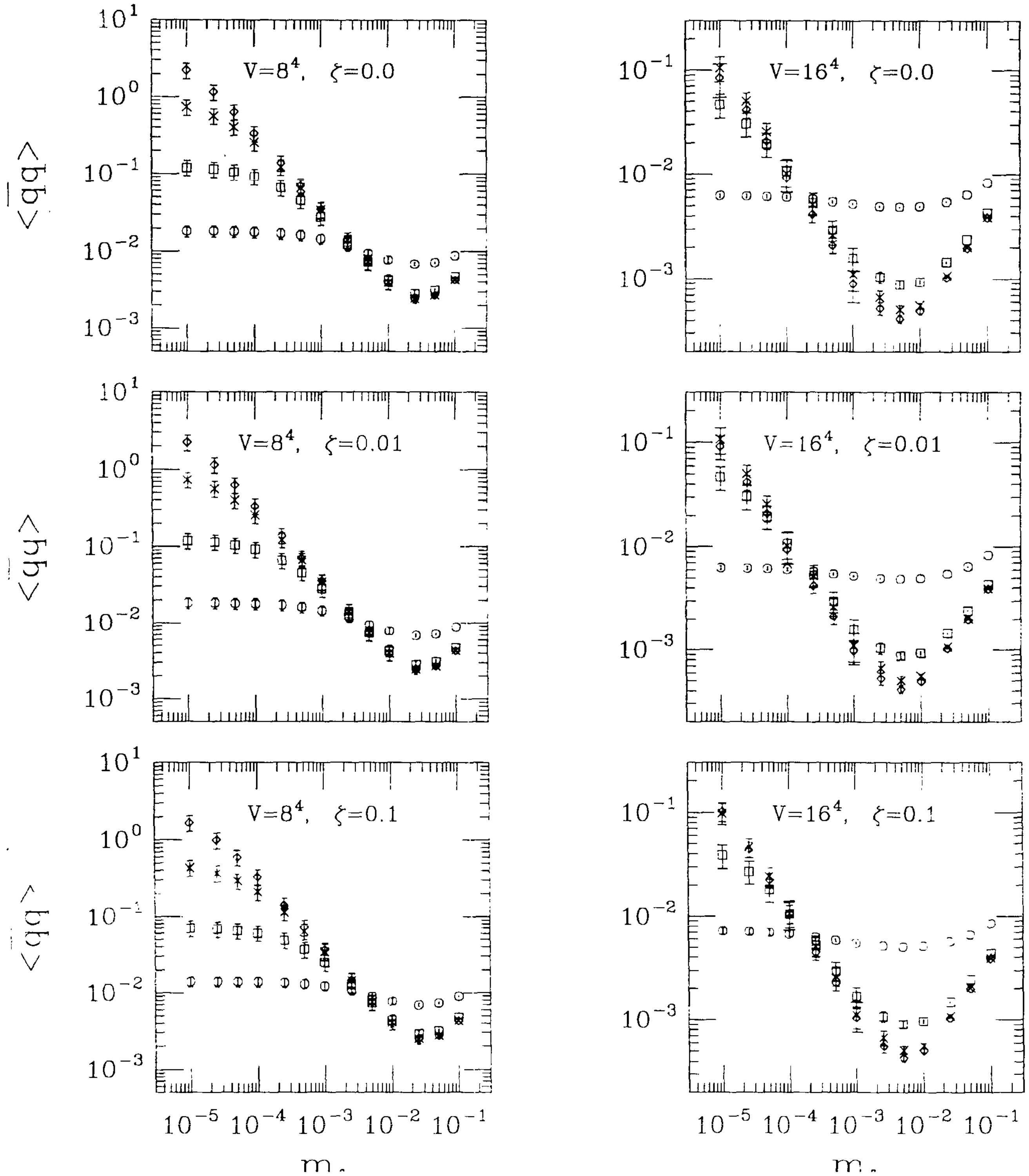


$$\langle \bar{\psi}\psi \rangle \sim m \int_0^{\infty} d\lambda \, \frac{\rho(\lambda)}{\lambda^2 + m^2}$$

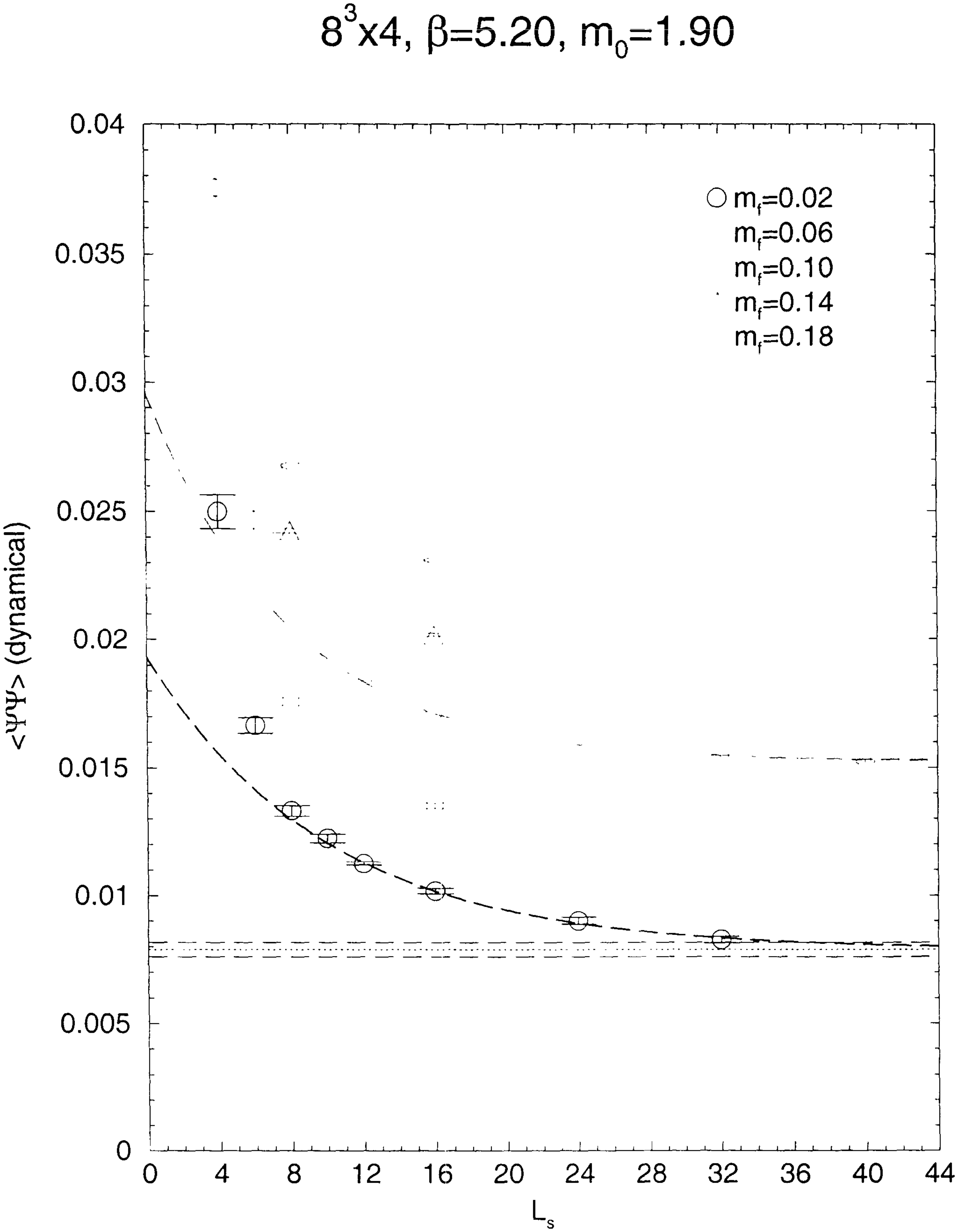
DWF - Smooth instanton configuration on lattice

ρ/a small

ρ/a large



add random noise



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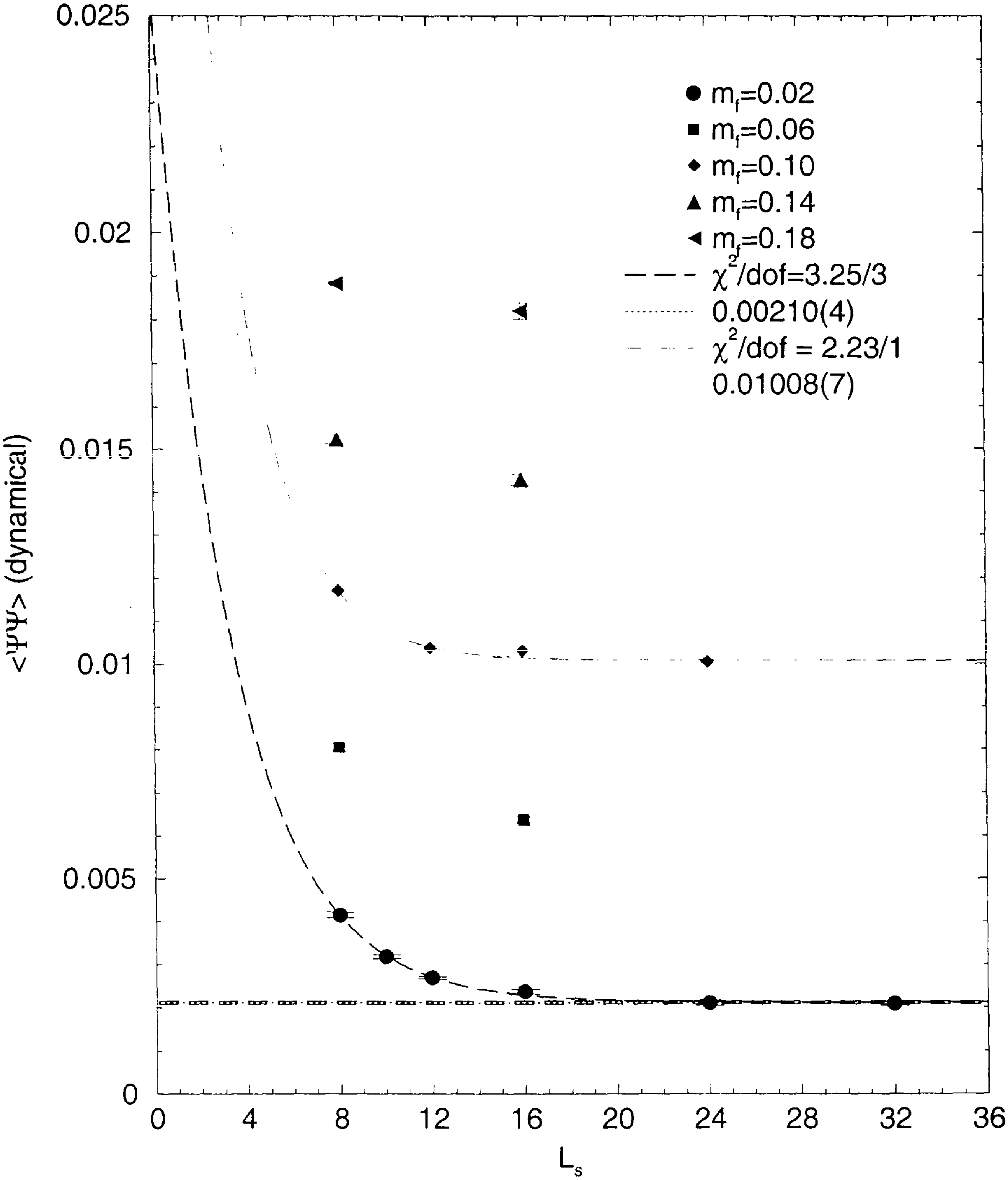
8^3x4, β=5.45, m_0=1.90



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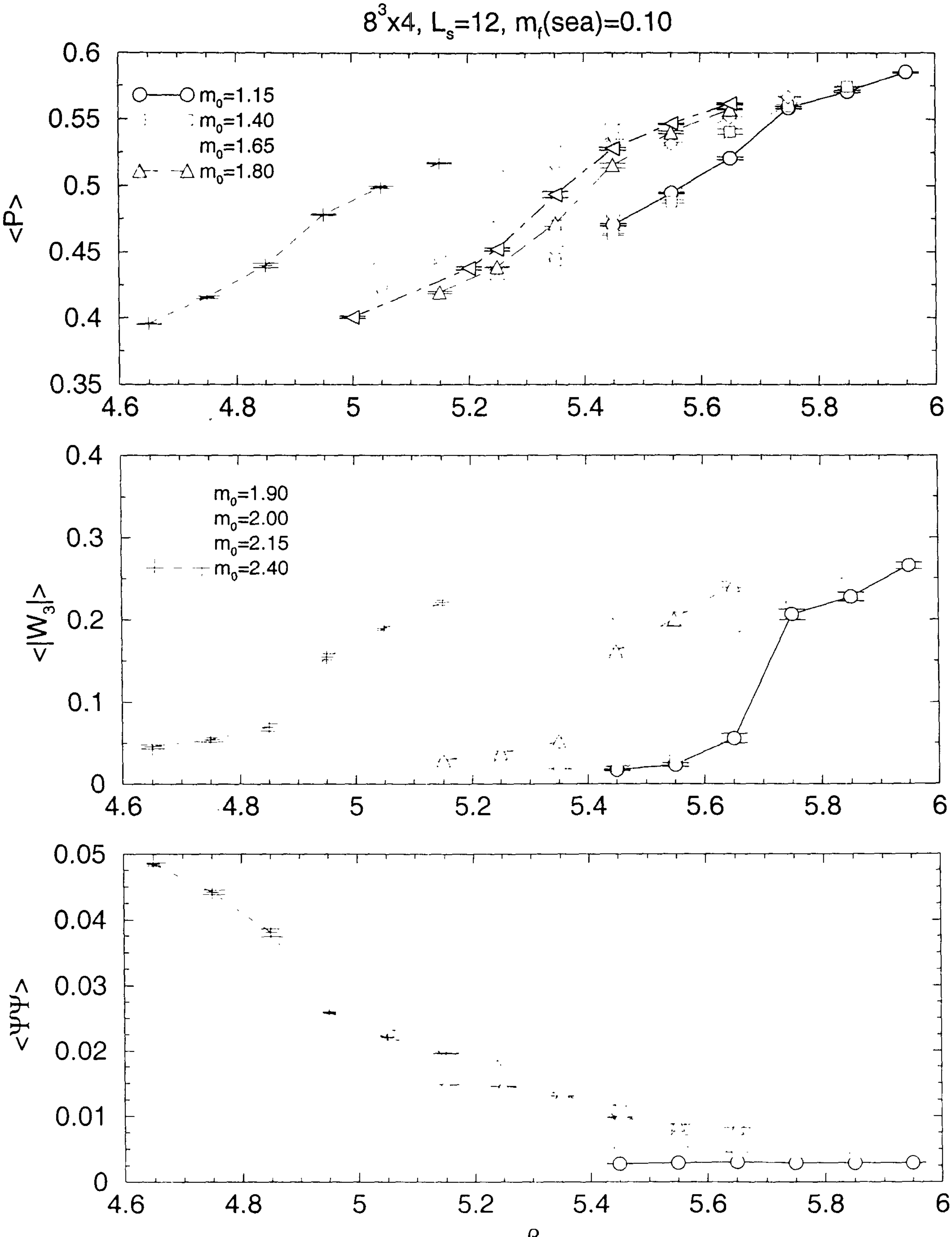

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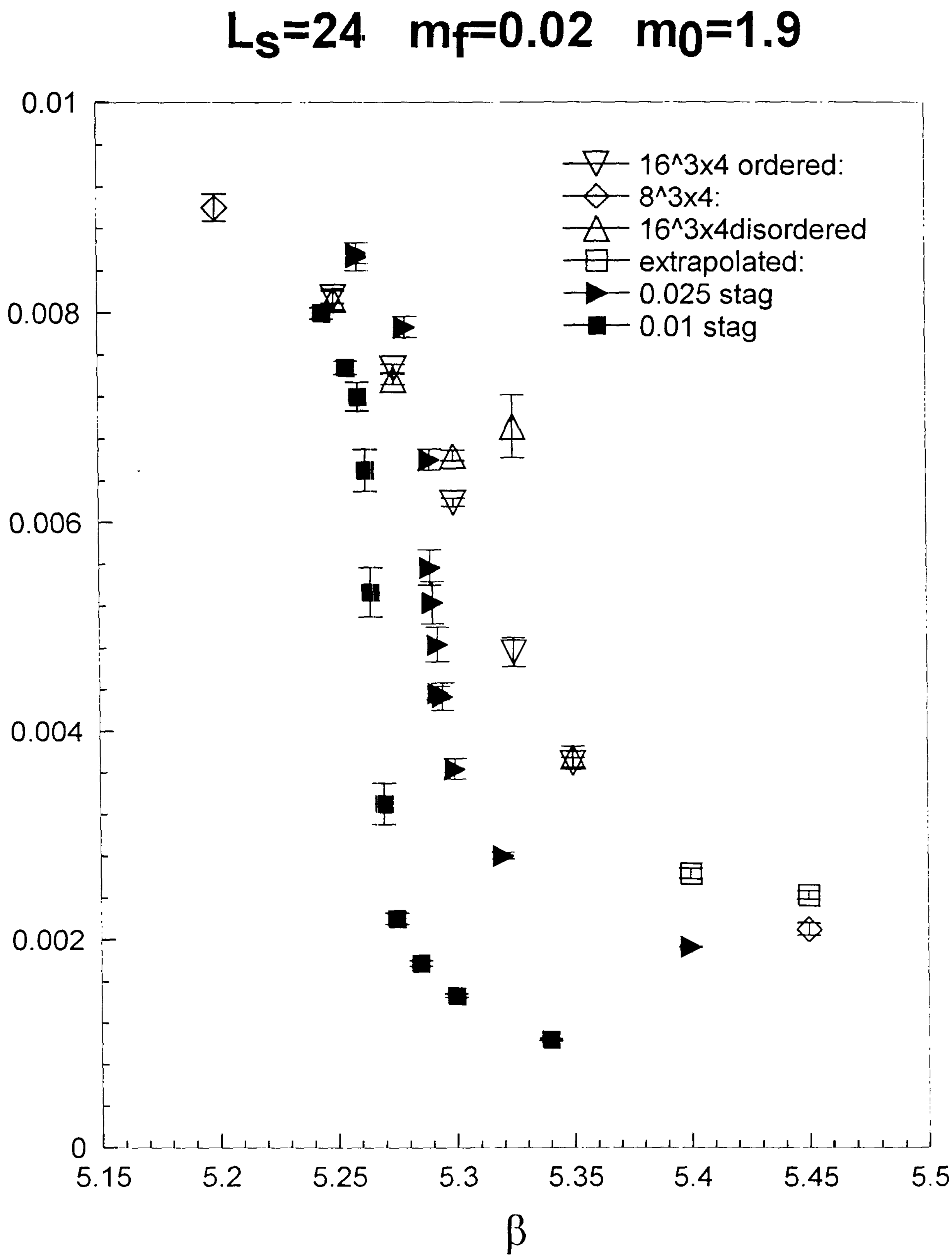


January 12, 1999

Conclusions

- 1 Teraflops QCDSP computers running.
- Domain wall fermions promising
  1. Quenched calculations underway to improve phenomenologically important parameters.
  2. Dynamical finite temperature simulations yielding results.
  3. Dynamical zero temperature simulations time consuming.
- Full staggered fermion QCD simulations progressing to weaker coupling on large volumes (2.5 fm).
- Reduced systematic effects expected.

The Next Step for Machines for the QCDSP Project

Norman Christ
Columbia University

The Next Step

- Faster processor
  Texas Instruments C67
  - 0.67 Gflops [0.05 Gflops]
  - 32K Words on-chip memory
    (holds 4^4 lattice) [2K Words]
  - 2 Watts
  - ~ #100.
- Faster communications
  - 200 MHz [50 MHz]
  - Phase-locked loop
- Larger memory $\geq$ 16 Mbyte
  [2 Mbyte]
- ~10 times cost/performance enhancement
  #1/Mflops [#10/Mflops]

EXPERIMENTAL PRESENTATIONS

RHIC Spin Physics and the Experimental Division of the Center

Gerry Bunce

RIKEN BNL Research Center Review
27 May 1999
Gerry Bunce

The Polarized Proton Collider at RHIC

-up to 250 GeV x 250 GeV

-70% polarization, each beam

-longitudinal polarization at Phenix, STAR

-transverse polarization at pp2pp, Brahms, Phobos

-120 bunches x 2 x 10^{11} polarized protons in each ring

-L = 2 x 10^{32} cm^{-2} sec^{-1} at root(s) = 500 GeV

Physics: To understand the proton—How is the spin of the proton made of its constituents?

-from scattering electrons and muons: the quarks in the proton carry only 1/3 of the proton spin

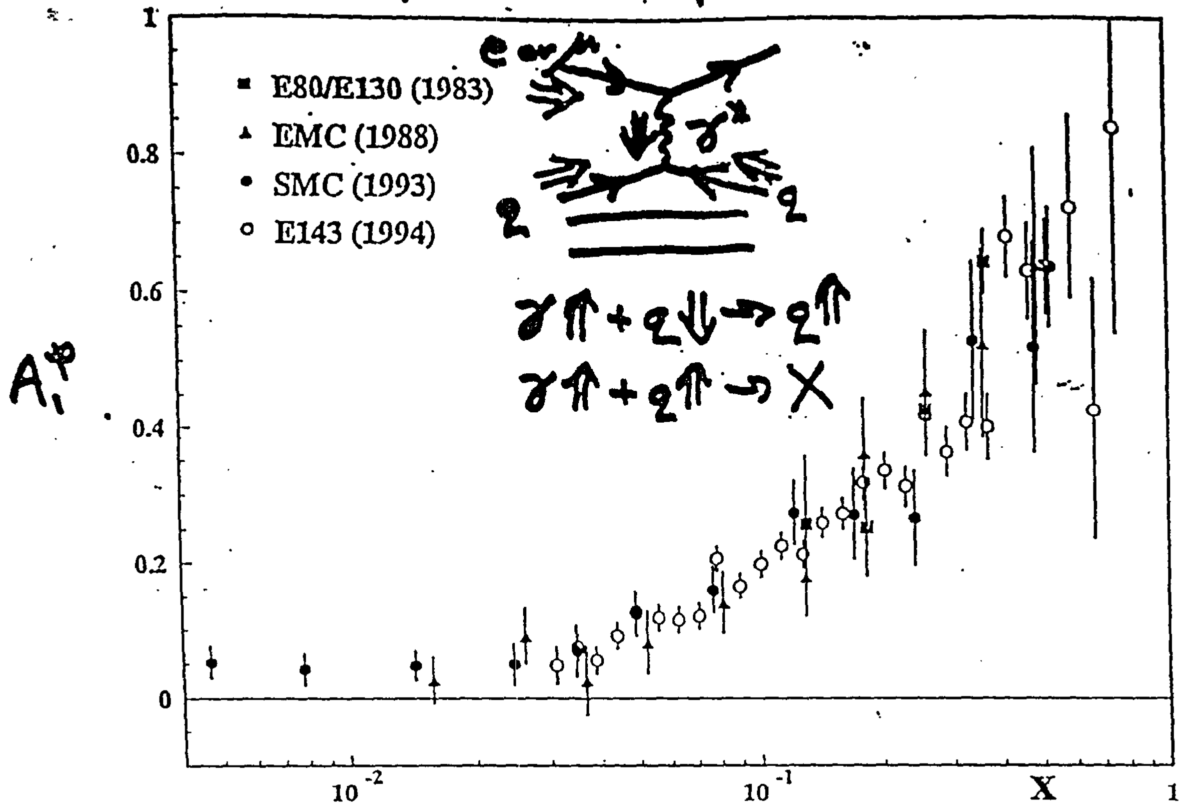
-RHIC will measure the polarization of the gluons, and the polarization of the u, ubar, d and dbar quarks in the proton

<u>Our schedule</u>:

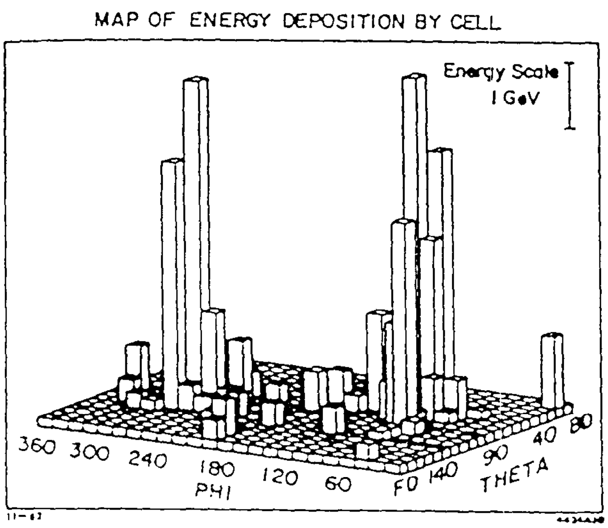
Spring, 2000--Commission 1 RHIC ring with polarized protons to 100 GeV

Spring, 2001--First spin physics run, 100 GeV x 100 GeV

At large x, quarks do carry proton spin.

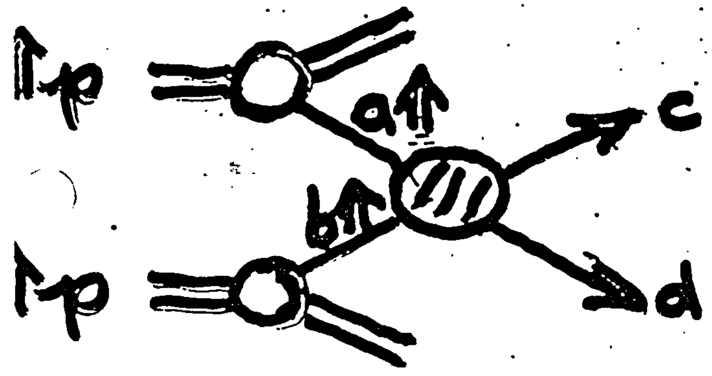


At high p_T, proton beam is a beam of quarks and gluons.



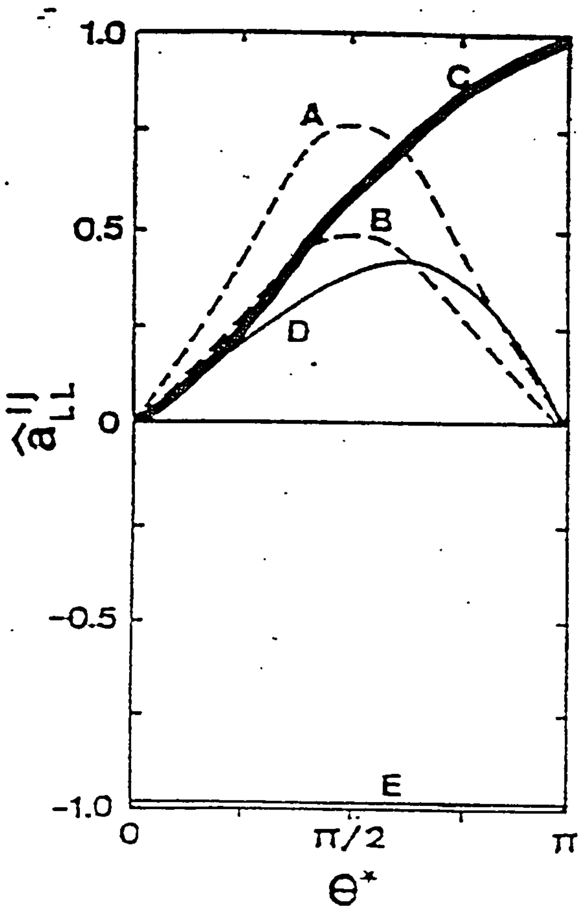
UA2, Paris Conf. 1982

At high p_T, polarized proton beam is a beam of polarized quarks.



$$A_{LL} \sim \frac{\Delta a}{a}\frac{\Delta b}{b}\hat{a}_{LL}(a+b \to c+d)$$

$\hat{a}_{LL}$ is large



A [$gg \to gg$

B [$dd \to dd$, $uu \to uu$

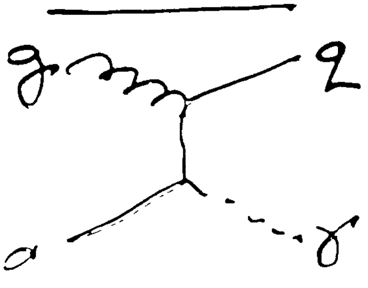
C [$ud \to ud$, $u\bar{d} \to u\bar{d}$, $d\bar{u} \to d\bar{u}$, $qg \to qg$, $qg \to q\gamma$

D [$u\bar{u} \to u\bar{u}$, $d\bar{d} \to d\bar{d}$

E [$gg \to q\bar{q}$, $q\bar{q} \to gg$, $u\bar{u} \to d\bar{d}$, $d\bar{d} \to u\bar{u}$, $q\bar{q} \to g\gamma$

direct γ probes ΔG

Direct γ

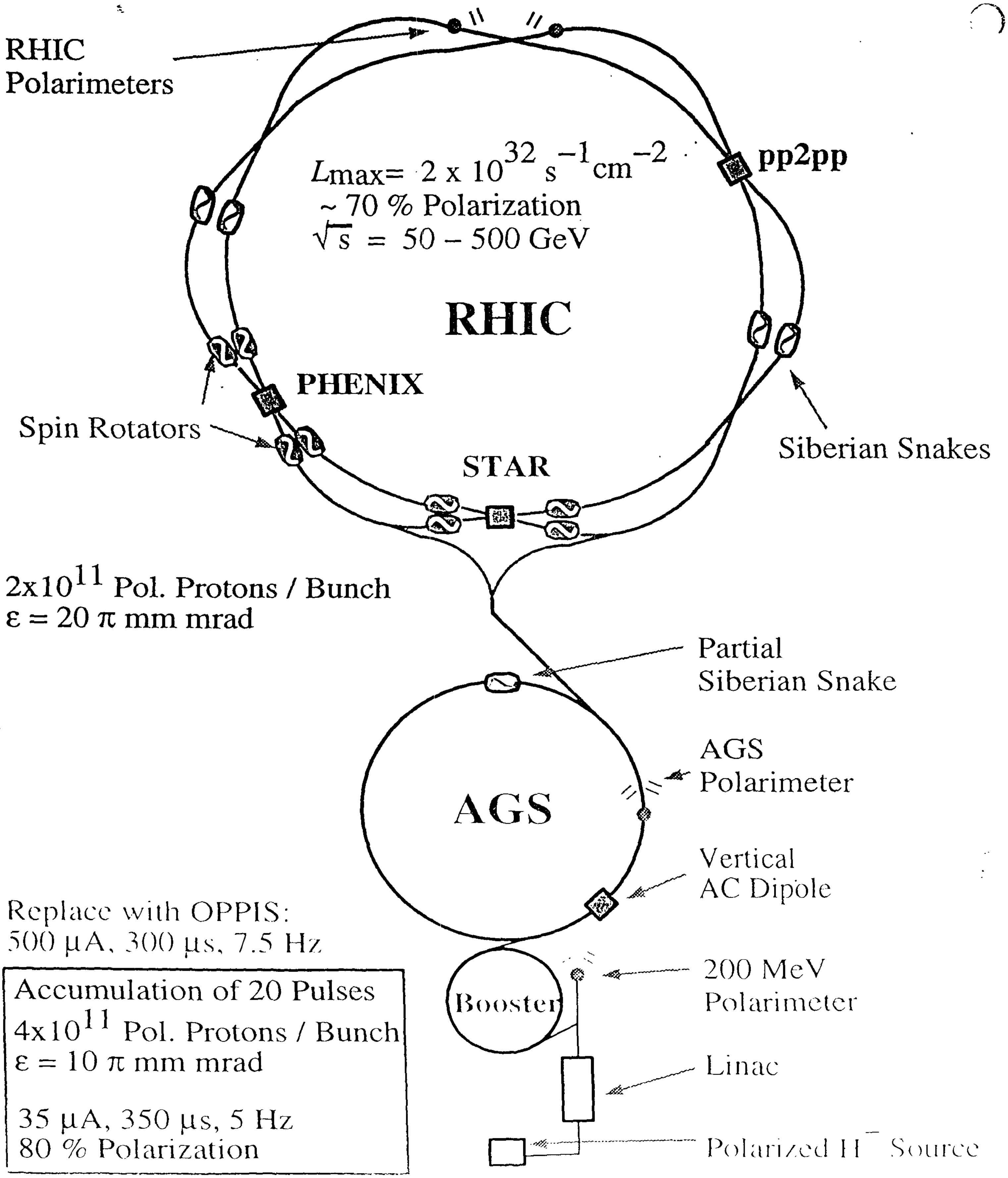


$$A_{LL} = \hat{a}_{LL}(qg \to \gamma q)\,\frac{\Delta G(x_1)}{G(x_1)}\,A_1(x_2)$$

$\hat{a}(90^\circ) = +.6$ $\qquad$ $A_1(.2) = .3$

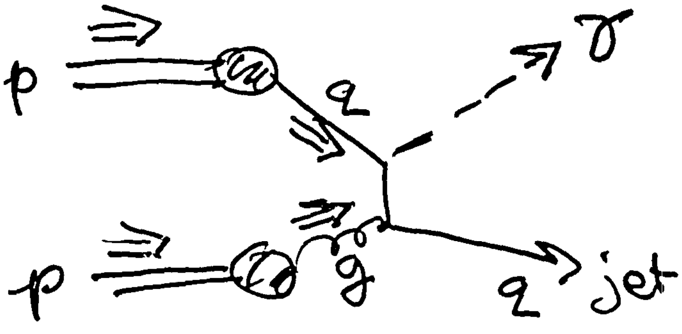
$$\therefore \frac{\Delta G}{G}(x_g) = \frac{A_{LL}}{.2} \text{ for } x_q = .2,\ 90^\circ$$

Polarized Proton Collisions at BNL



RHIC Spin Probes

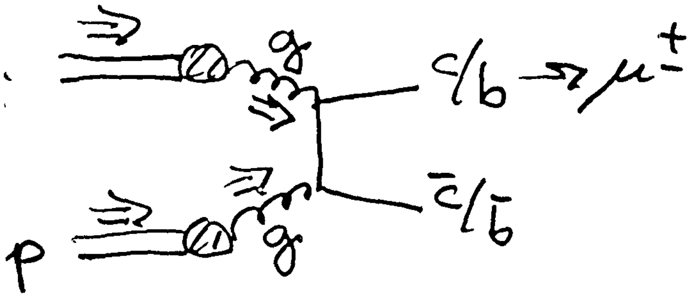
Gluon polarization:



$$A_{LL} = \frac{\Delta G}{G}(x_g)\, A_1^p(x_q)\, \hat{a}_{LL}$$

$(.3)$ $(.6)$

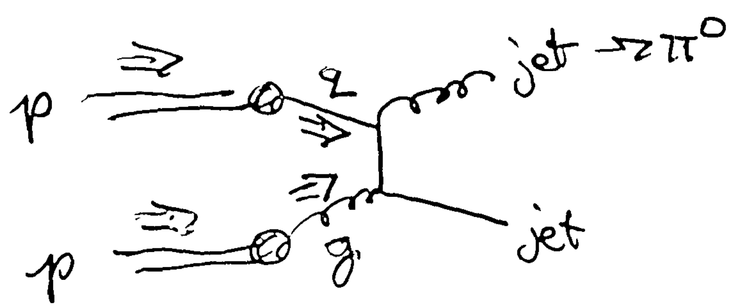
$$\simeq \frac{1}{5}\frac{\Delta G}{G}(x_g)$$



$$A_{LL} = \frac{\Delta G}{G}(x_1)\,\frac{\Delta G}{G}(x_2)\,\hat{a}_{LL}$$

$(.5?)$ $(.15)$

$$\overset{?}{\simeq} \frac{1}{12}\frac{\Delta G}{G}(x_1)$$



$$A_{LL} = \frac{\Delta G}{G}(x_1)\,\frac{\Delta u}{u}(x_2)\,\hat{a}_{LL}$$

$(.4)$ $(.6)$

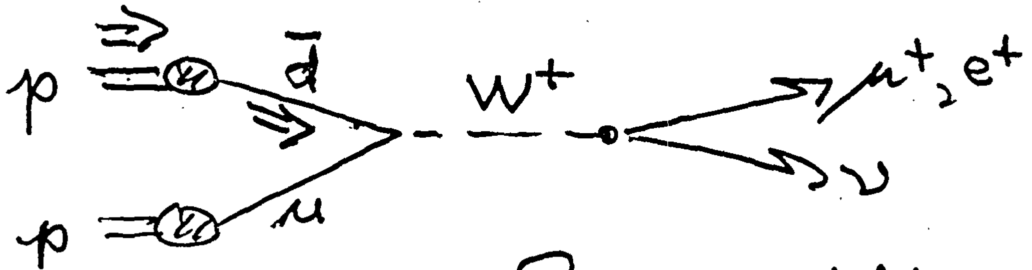
$$\simeq \frac{1}{4}\frac{\Delta G}{G}(x_1)$$

$+\, gg \to gg/q\bar{q}$

also J/ψ (but production mechanism)

Probes (cont.)

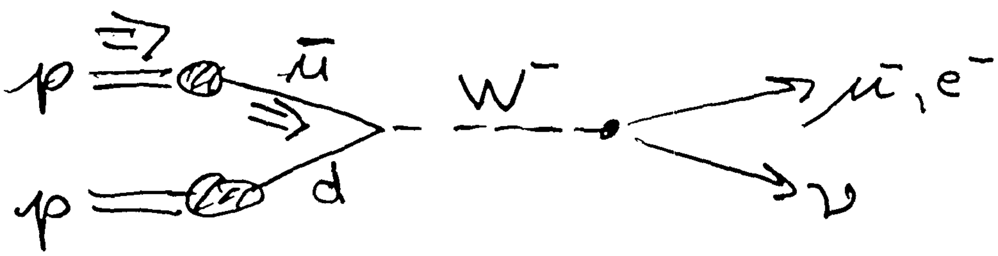
Quark polarization by flavor



Parity violation of W production

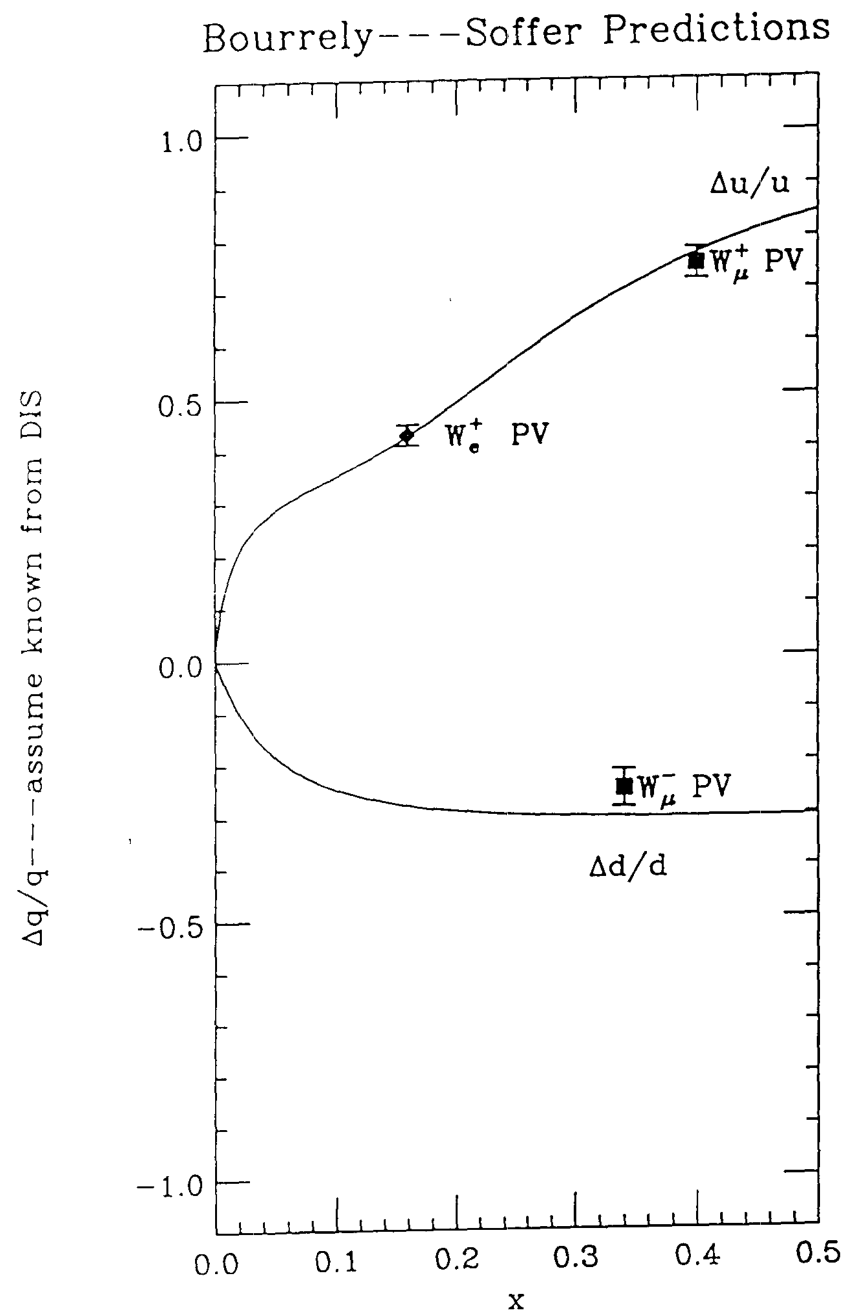
$A_L \approx \dfrac{\Delta \bar{d}}{\bar{d}}$ for W^+ backward from polarized p

$A_L \approx \dfrac{\Delta u}{u}$ for forward W^+

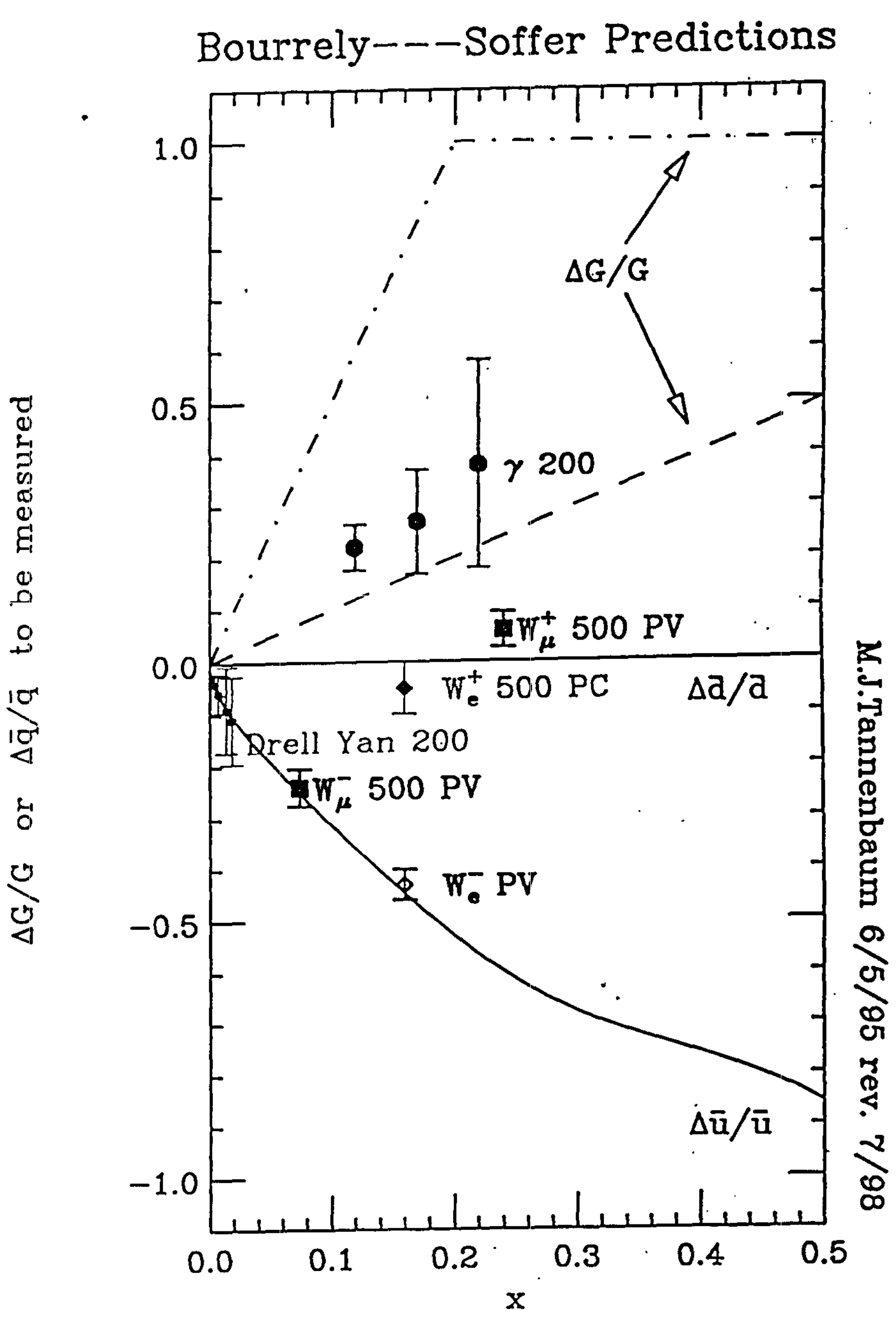


$A_L \approx \dfrac{\Delta \bar{u}}{\bar{u}}$ for W^- backward.

$A_L \approx \dfrac{\Delta d}{d}$ for W^- forward.



Bourrely---Soffer Predictions
Δq/q---assume known from DIS
Δu/u
W_μ^+ PV
W_e^+ PV
W_μ^- PV
Δd/d
1.0
0.5
0.0
−0.5
−1.0
0.0
0.1
0.2
0.3
0.4
0.5
x



Bourrely---Soffer Predictions
ΔG/G or $\Delta\bar{q}/\bar{q}$ to be measured
ΔG/G
γ 200
W_μ^+ 500 PV
W_e^+ 500 PC
$\Delta\bar{d}/\bar{d}$
Drell Yan 200
W_μ^- 500 PV
W_e^- PV
$\Delta\bar{u}/\bar{u}$
1.0
0.5
0.0
−0.5
−1.0
0.0
0.1
0.2
0.3
0.4
0.5
x
M.J.Tannenbaum 6/5/95 rev. 7/98

RHIC Spin Collaboration and the Center

Spin physics must involve a close collaboration between theory, experiment, and the accelerator →RHIC Spin Collaboration

The RSC formed in 1991 after the Polarized Collider Workshop at Penn State. It developed the physics case, the accelerator spin plans, and proposed the RHIC spin physics program to the PAC, with the Phenix and Star collaborations. The spin program was approved in 1993.

In 1995 the RIKEN-BNL agreement was signed with support from RIKEN for the siberian snakes, and a 2nd muon arm for Phenix for spin.

The Center, which celebrated its first year last fall, offers an incredible and unusual opportunity to fully realize all of the physics at RHIC. For the spin program, the Center, with both theory and experimental divisions, is ideal.

Our goals with the Experimental Division are to

- —fully develop the potential of the RHIC spin program
- —do this through joint work with RIKEN staff
  - —very strong group
  - —connects directly and deeply with young physics community in Japan

Some practical issues on forming Experimental Division:

Size —important to have close working relationships → <10 (7)

Topics —cover several important spin topics, but maintain focus and cohesiveness of group

Technicians —no standing group of technicians →collaboration with RIKEN, Japanese Universities, BNL Medium Energy Group

Heavy ions —cover heavy ions and spin →most work does this but for now we emphasize spin for Fellows

STAR —cover Star as well as Phenix →future, will also be done by BNL Medium Energy Group

Theory —strong connection with theory →RBRC Theory Division, Spin Discussions, Workshops

Accelerator —strong connection with accelerator →Thomas Roser as advisor, would like to have RA work with Thomas

Young staff —"season" with advisory group, also BNL Medium Energy Group (future)

Support —funds for smaller initiatives (polarimeter, luminosity, trigger), apply for funds for larger apparatus

Students —important!—RIKEN staff, Kyoto, Tokyo Institute of Technology, possibly expand this

RBRC Experimental Division

Masayasu Ishihara — Group Leader

Gerry Bunce — Deputy Group Leader

Naohito Saito — leads RIKEN staff at BNL

RBRC Fellow — Matthias Grosse Perdekamp

RBRC Research Associate — Alexander Bazilevsky

RIKEN Staff at BNL — Naohito Saito, Kazu Kurita, Atsushi Taketani, Yuji Goto, Masahiro Okamura, Yajun Mao, Jiro Murata, Naoki Hayashi

Students from Kyoto and TITech at BNL — Hiroki Sato, Hisayuki Torii, Junji Tojo, Etsuji Taniguchi, Makoto Sugioka

Advisors — Bob Jaffe, Yousef Makdisi, Mike Tannenbaum, Thomas Roser

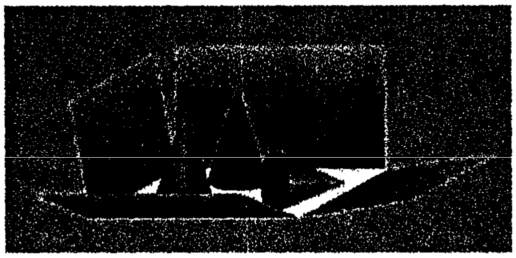
Visiting Scientists — Masa Ishihara, Yashushi Watanabe, Takashi Ichihara, Ken-ichi Imai, Hideto En'yo, Toshi-Aki Shibata

Spin Work of the Roundtable Group

Naohito Saito

Spin Work by Roundtable Group

Scientific Review of RBRC, May 27-28, 1999



Outline:
- RHIC Spin Program
- RT Activities
- Summary

Naohito Saito

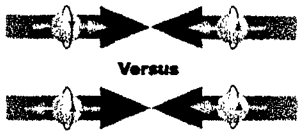
RIKEN / RIKEN BNL Research Center

Spin Physics at RHIC

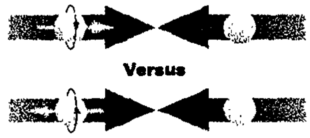
- Spin Structure of the Nucleon
  - $\Delta g(x)$: Gluon polarization via γ,π^0,heavy quark productions
  - $\Delta\bar{q}(x)$: Anti-quark polarization via Drell-Yan (W,Z,γ^*)
  - $\Delta_T q(x), \Delta_T \bar{q}(x)$: Quark transversity
- Symmetry Tests
  - parity violating effects, e.g. compositeness
- QCD Selection Rule
  - switch off gluon; $a_{TT}/a_{LL} << 1$
- Single Transverse Spin Asymmetry A_N
  - large at lower Energy; higher-twist? ; k_T asymmetry?

Spin Physics Program

discussed at RSC mtg



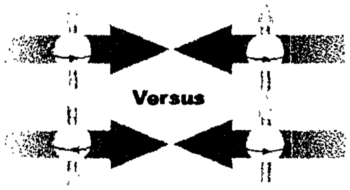
- A_{LL} measurements at 200 GeV
  - to answer urgent question on ΔG
    - EMcal should be ready for π^0 and prompt γ
    - Muon Arm should be ready for J/ψ and Open charm, beauty and DY
    - P_B should be known to 10% precision
- A_{LL} and A_L measurements at 500 GeV
  - direct measurement of parity violation, Δq_i
    - Two Muon Arms should be ready for Z^0/W
    - P_B should be known to 5% precision
  - enhance kinematical coverage for ΔG

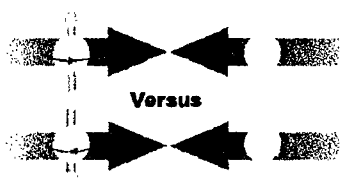


Spin Physics Program-2

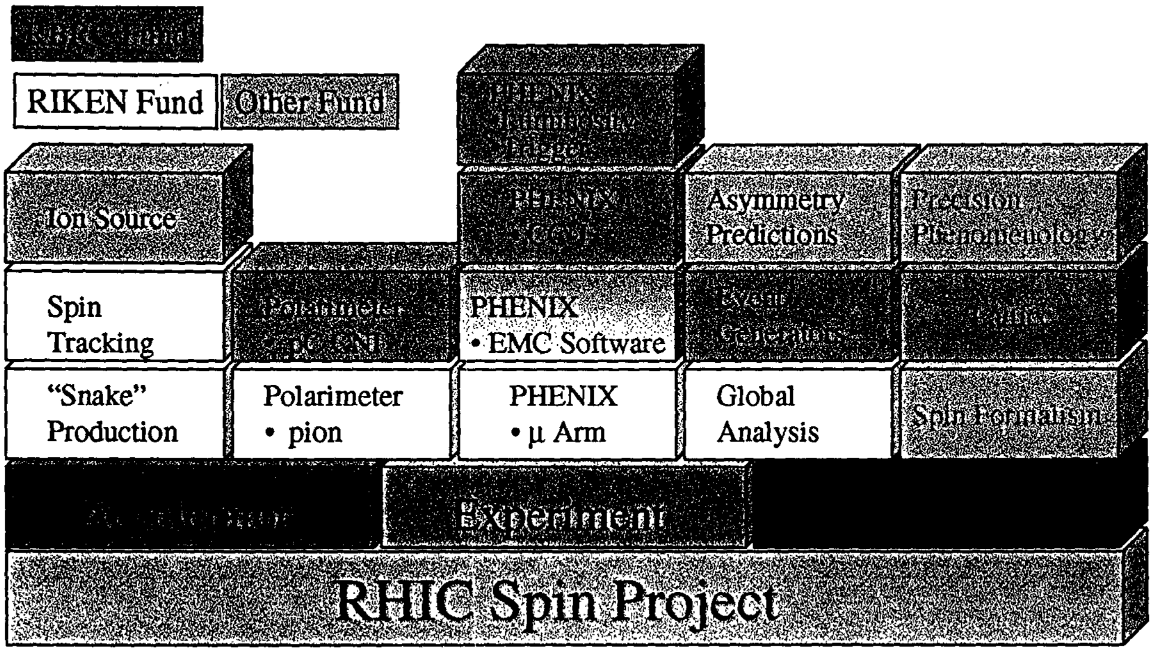
discussed at RSC mtg

- A_{TT} and A_N measurements
  - transversity, QCD selection rule (switch off gluon effects)
  - higher twist effects





RHIC Spin Project



Activities-1

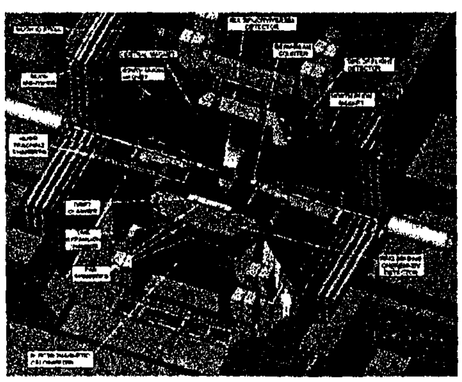
- PHENIX Experiment
  - Muon Arm (W, J/ψ, Open Heavy Flavor)
    - magnet, muon ID, software, tracking chamber, trigger, beam test of muon ID

    Takashi, Yasushi, Atsushi, Kazu, Yajun, Jiro, Hiroki, Etsuji, Junji, Toshi-Aki, Ken, Hideto, Naohito
  - EM Calorimeter (π^0, Prompt γ, η)
    - high energy beam test, online, offline, trigger

    Yuji, Hisayuki, Naohito, Matthias, Sasha
  - Luminosity Monitoring

    Gerry, MikeT, Hideto, Yuji, and Naohito
  - CC-J

    Takashi, Yasushi, Naoki, Hideto, Yuji, Naohito

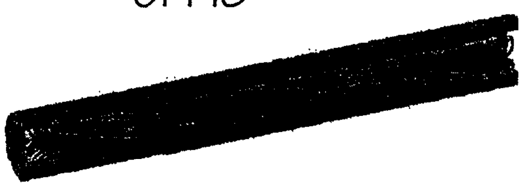


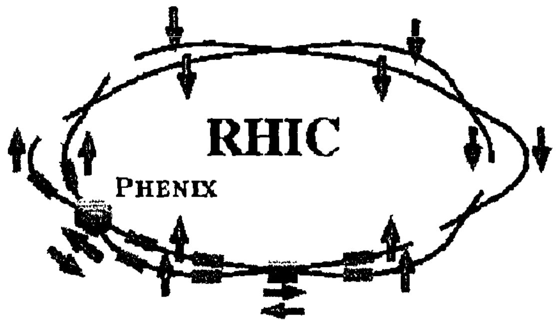
Activities-2

- Accelerator

  Thomas, Masahiro, Gerry, Yousef, Naohito

  – Design, Production and QA of Helical Dipole Magnet
  – Spin Dynamics
  – OPPIS





Activities-3

- Polarimeter
  – large x_F π polarimeter

    Yousef, Naoki, Yuji, Hiroki, Hideto, Naohito, Sasha, Matthias, Gerry

  – pC CNI polarimeter

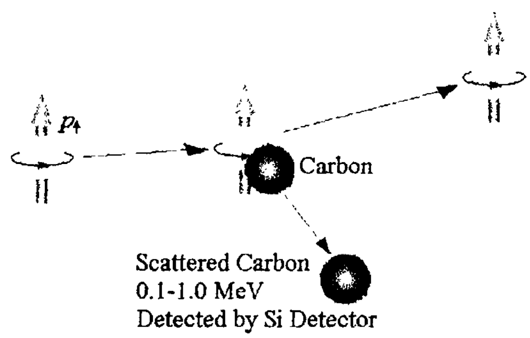
    Kazu, Ken, Junji, Atsushi, Gerry, Naohito

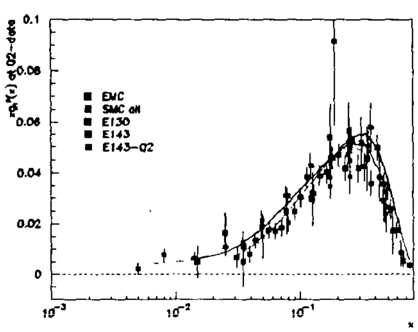
- Spin Physics
  – Global Analysis of polarized PDF

    Naohito, Toshi-Aki, Yuji, Naoki, Etsuji

  – Event Generator

    Naohito, Toshi-Aki, and many





Spin Discussion@BNL

weekly discussion among exp, thry and acc

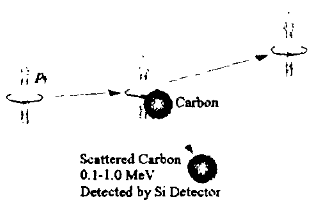
- Initiated by Bob and Gerry -> Werner and NS
  - *web master: Yuji*
- Forum to Discuss Various Issues on Spin Physics
- Topics:
  - RHIC Spin measurements
    - theory: formalism, phenomenology, and lattice
    - *experiments: sensitivity, systematic uncertainty*
  - Experiments relevant to RHIC Spin program
  - Experimental Technique including Accelerator
  - Relevant Conference Report

Workshops

- Useful in Defining Direction of RBRC-E Works
- RHIC Spin Physics: Rhic Spin Collaboration

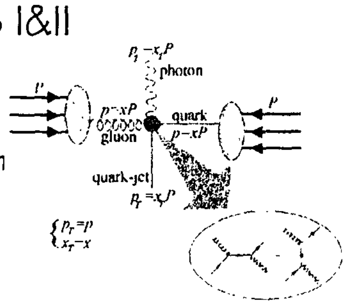
  (Gerry Bunce, Yousef makdisi, Naohito Saito, Mike Tannenbaum, Larry Trueman, and Aki Yokosawa)
- Physics of RHIC Polarimetry

  (K. Imai and D. Fields)
  - Experiment on *pC* CNI polarimeter proposed



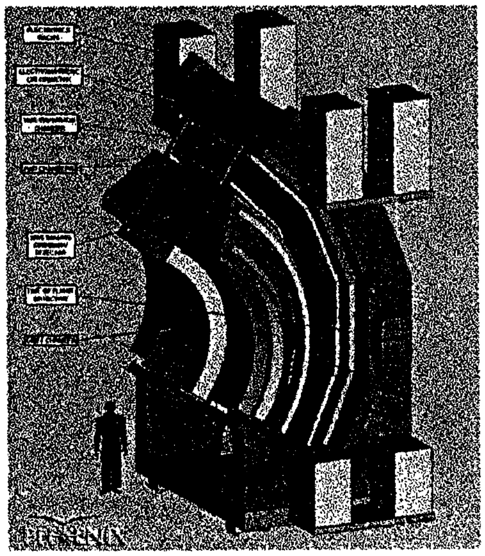
- Event Generator for RHIC Spin Physics I&II

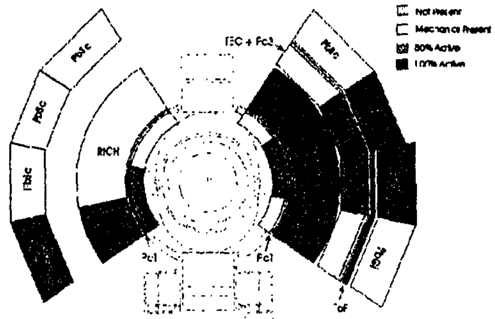
  (N. Saito and A. Schaefer)
  - Working Group has been established
    - prompt photon problem: kT, resummed xsection calculation
  - Problems in current EvGen identified

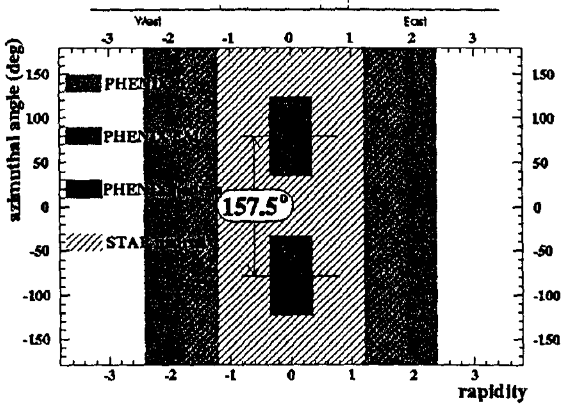


PHENIX Central Arms

- Equipped with Finely Granulated Emcalorimeter ($\Delta\phi \sim \Delta\eta \sim 0.01$)



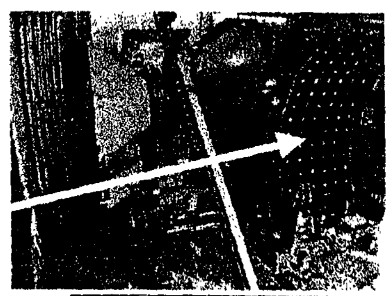


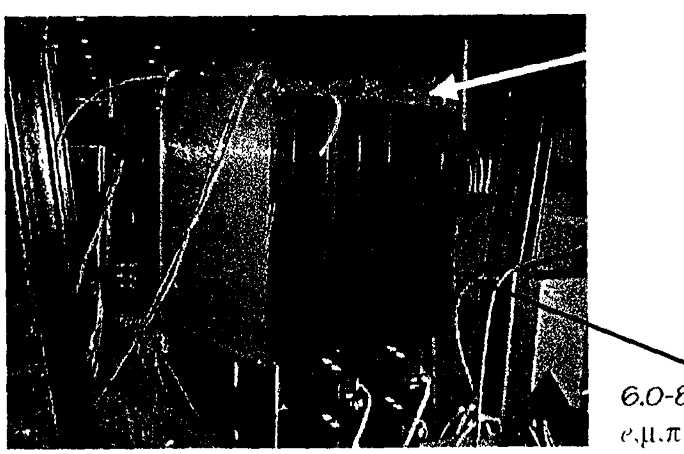


High Energy Beam Test of PHENIX EMCal @ CERN

(proposed and lead by Yuji Goto)

- GOAL: Understand Response to Hi-Energy Particles
  - Energy Resolution, Linearity, Hadron Response, Shower Profile



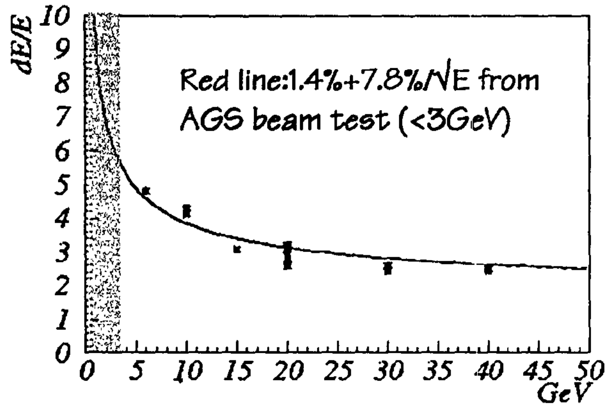


6.0-80.0 GeV
e,μ,π beam

Results from HEBT@CERN

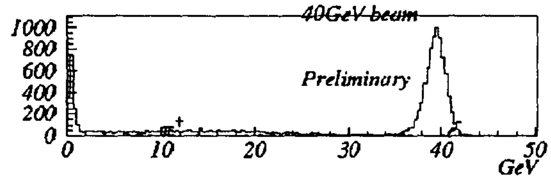
(preliminary: Hisayuki-Yuji)

- Energy Resolution
  almost consistent with expectation from low-E AGS test and simulation

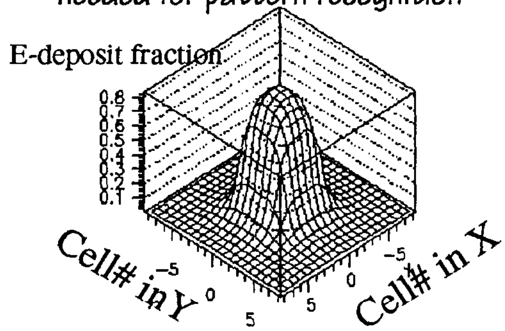


- Energy Linearity
  non-linearity<2%

- Hadron Response
  Rejection (E-p match alone) >100



- Shower Profile: E-deposit Pattern
  needed for pattern recognition



Summary

- Roundtable provides a bridge of RBRC-E and RIKEN-BNL activities
  - successful integration of RBRC-E activities into existing RIKEN-BNL activities
  - close relationship between RBRC-E and RIKEN-BNL activities will be continued for the success of RHIC Spin Physics

Work on the Electromagnetic Calorimeter of PHENIX

Alexander Bazilevsky

Sasha Bazilevsky
RIKEN-BNL Research Center

PHENIX EMCal

Its characteristics
Methods for data analysis

RBRC Scientific Review
May 27-28, 1999

EMCal primary role in PHENIX

Electron and photon identification, measuring their parameters

Provide the means to trigger on events where electrons and photons are produced with a high transverse momentum

It'll also provide additional particle identification by combining calorimeter time with amplitude information; trigger on events with jetlike structures or events with high transverse energy flow

[redacted]

Phase transition: π^0 measurements

Debye screening: $J/\psi \rightarrow e^+e^-$

Chiral Symmetry restoration: $\phi \rightarrow e^+e^-$

Thermal Radiation of Hot Gas: prompt γ

[redacted]

ΔG: High p_t γ and π^0 production

$\Delta\bar{q}$: $W^{\pm}$ production

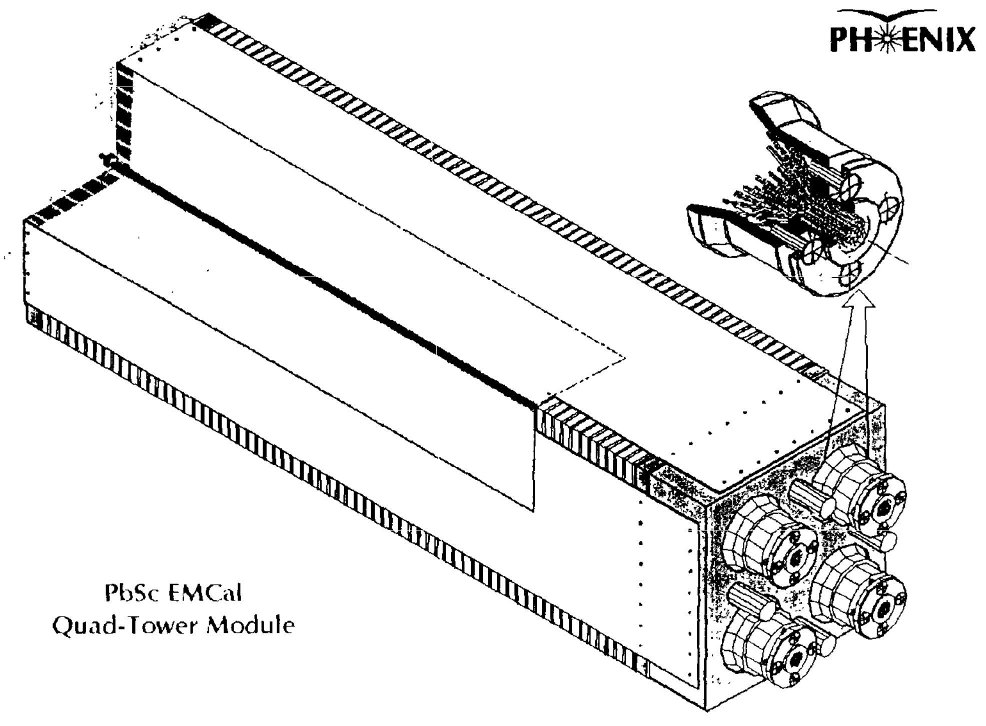
EMCal construction

8 sectors: 2 (PbGl Cerenkov) + 6 (PbSc Sampling) ≈ **25,000 cells**

η coverage: ±0.35 $\Delta\eta$(cell) = 0.01

ϕ coverage: 180^0 $\Delta\phi$(cell) = 0.01

PbSc Module (4 cells)



EMCal issues

Very wide energy range 0.3÷80 GeV

Very wide impact angle range $0^0 \div 20^0$

Very High Multiplicity (in Heavy Ions Collisions)

PbSc EMCal characteristics

Based on Test Beam (BNL and CERN) and simulated data analysis

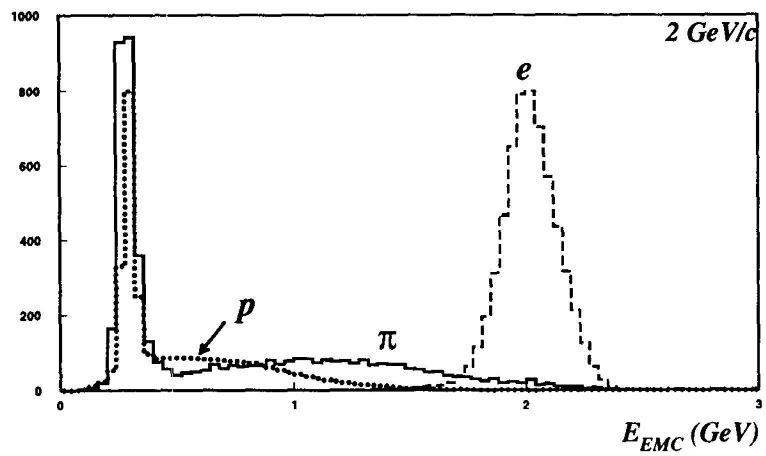
Energy resolution
photons, electrons: $\frac{\sigma_E(E)}{E} = \frac{7.35\%}{\sqrt{E}} \oplus 2.1\%$

Position resolution
photons, electrons: $\sigma_x(E,\theta) = \left(1.55 + \frac{5.7}{\sqrt{E(GeV)}}\right) \oplus (16 \cdot \sin(\theta))\ (mm)$

(Cell size – 55×55 mm^2)

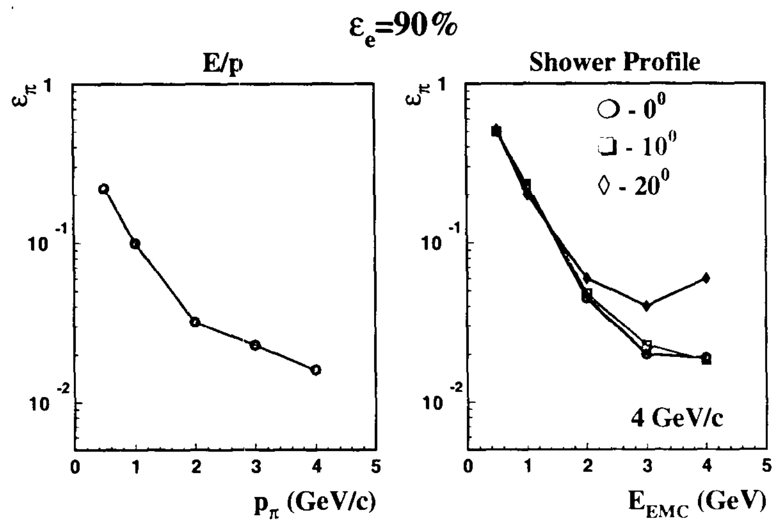
Time resolution
Pions: $\sigma_t(E) = 0.21 + 0.04/(E - 0.03)\ (nc)$
Electrons: $\sigma_t(E) = 0.06 + 0.03/(E - 0.01)\ (nc)$

EMCal response



$e(\gamma)/\pi$ rejection

- E/p matching: $|E_{EMC} - pc| < \alpha\,\sigma_E$
- Lateral shower profile: χ^2 criterion



EMCal pattern recognition

3 levels

1. Cluster:

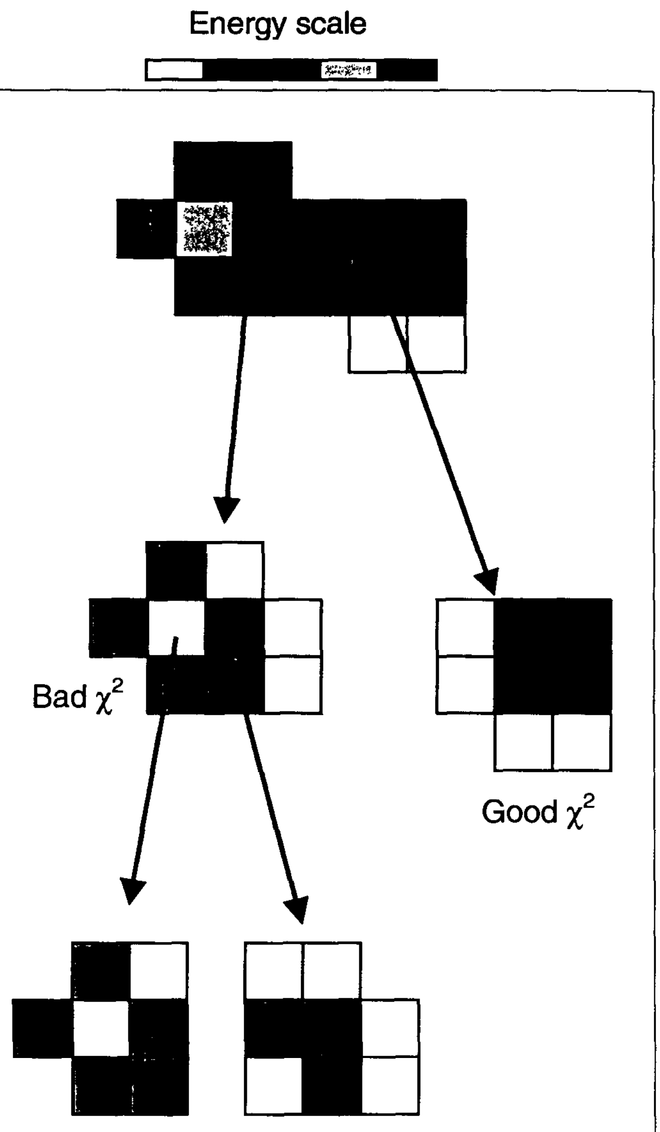
Cluster may contain several peaks (local maxima); the energy in towers is shared according to the energies expected from the photons located in each peak; Generates PeakArea's (sub-clusters after energy sharing)

2. PeakArea

Generates one or two EMshowers based on shower profile (χ^2 test)

3. EMshower

Consider all the activity in calorimeter (cluster) as only electromagnetic



Why we do really need several levels

Cluster ⇒ PeakArea ⇒ EMShower

- **We have to use different approaches for different tasks**
- **The EMCal response is very different for different particles:**

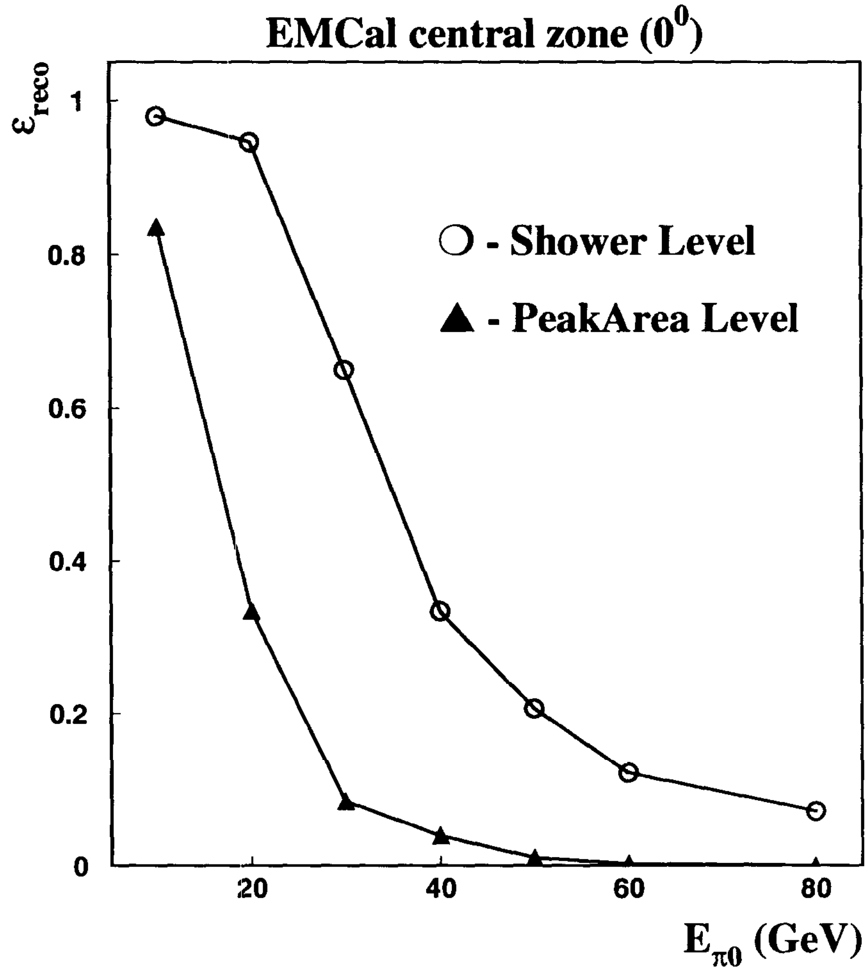
  Antibaryons: give one (sometimes several) Cluster with more then one Local Maxima ⇒ we split them on the PeakArea level ⇒ PeakArea and EMShower level can not be used here

  Pions: 15% of 1 GeV and 45% of 4 GeV hadronic showers give clusters with more then 1 Local maxima ⇒ the usage of PeakArea level is limited, EMShower level can not be used

  Photons&Electrons: in Low Multiplicity Events any level can be used; in High Multiplicity Events most of the Clusters and PeakAreas have more then 1 contributor ⇒ EMShower level helps us to clean the EM Showers

- **The shower parameter (for example, position) correction is very different for EM and Hadronic Showers with non orthogonal impact (because of the different penetration depth): the difference for 1 GeV showers with 20^0 impact could be ~1.5÷2 cm !!**

High p_t π^0 recognition efficiency



Summary

- The PHENIX EMCal amplitude and time responses are investigated; energy, position and time resolutions are studied and parameterized
- The methods for data analysis in the impact angle range $0^0 \div 20^0$ are proposed
- Multilevel pattern recognition procedure in the EMCal is proposed. **Now it's accepted as an official EMCal offline software in PHENIX**

Further tasks

- Cluster-Track association $\Rightarrow$ Charged Hadron rejection
- Photon and π^0 reconstruction in HIJING (Au-Au) and PYTHIA (p-p) events (using Time-of-Flight, Shower Profile and Tracking)
- Clustering (Pattern Recognition) Procedure implementation into online system

RHIC Spin: Online Monitoring and Transverse Spin

Matthias Grosse Perdekamp

RHIC Spin: Online Monitoring and Transverse Spin

Matthias Grosse Perdekamp
Riken BNL Center, May 27

- Spin specific needs in Online Monitoring

  Spin: "Online Observables"

  EMCal Online Calibration

- Transverse Spin

  Single Spin Asymmetries at Hermes

  Analysis of SMC Data

  Implications for RHIC

Online Monitoring

Phenix Standard: Subsystem Calibration and Monitoring, Slow Control

Spin specific : Luminosity L, Beam Polarization P, Acceptance a

Example:

Extract

$$A_{LL} = \frac{(\sigma^{++} + \sigma^{--}) - (\sigma^{+-} + \sigma^{-+})}{(\sigma^{++} + \sigma^{--}) + (\sigma^{+-} + \sigma^{-+})}$$

From Yields

$$N^{++}, N^{--}, \ldots = \sigma \sum_{\substack{i=bunch \\ crossings}} (1 + P_i^{2++} A_{LL}) \int L_i^{++}(t) a_i^{++}(t) dt$$

⇒ Record $L(t), P_b(t), a(t)$

⇒ Optimize $P_b^2 N$

⇒ Stability Limits

Develop Skills in PHENIX ONCS

Status of EMCal Online Calibration + Monitor

Task	Organization
I/o	Kyoto, RBRC
Decoding	BNL, Münster, ORNL
Ring Buffer	Münster
Calibration	BNL, ORNL, RIKEN, RBRC
Trouble Shooter	Nantes
Muon Tracking	BNL
Clustering	
Gain Balance	

February 99

Required for Engineering Run — May 15

Completed — May 21

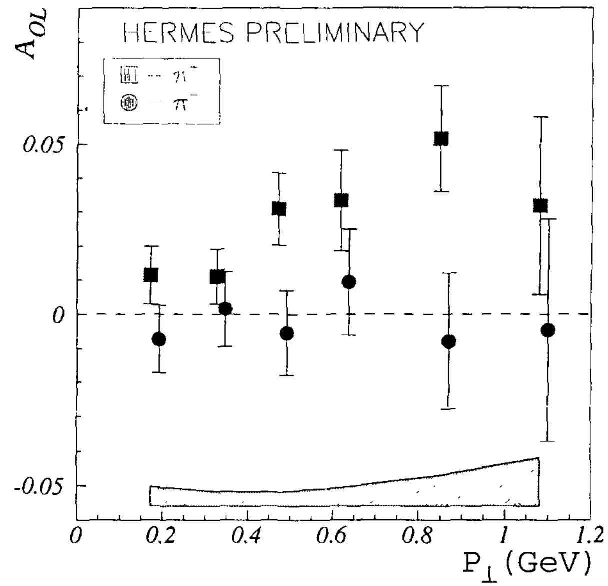
Required for Physics Run — November 99

Kyoto: Hisayuki Torii
RIKEN: Yuji Goto
RBRC : MGP

Transverse Spin

Single Spin Asymmetry reported at DIS99

$$A_{OL} = \frac{\int_\phi \sin\phi \, d\sigma^+/d\phi}{P^+_{\text{targ}} \int_\phi d\sigma^+/d\phi} - \frac{\int_\phi \sin\phi \, d\sigma^-/d\phi}{P^-_{\text{targ}} \int_\phi d\sigma^-/d\phi}$$



Twist 2 vs Twist 3? -> SMC Data at different Q^2 !

Plans:

- Is A_{OL} present in SMC data sample?
- Expectations for RHIC

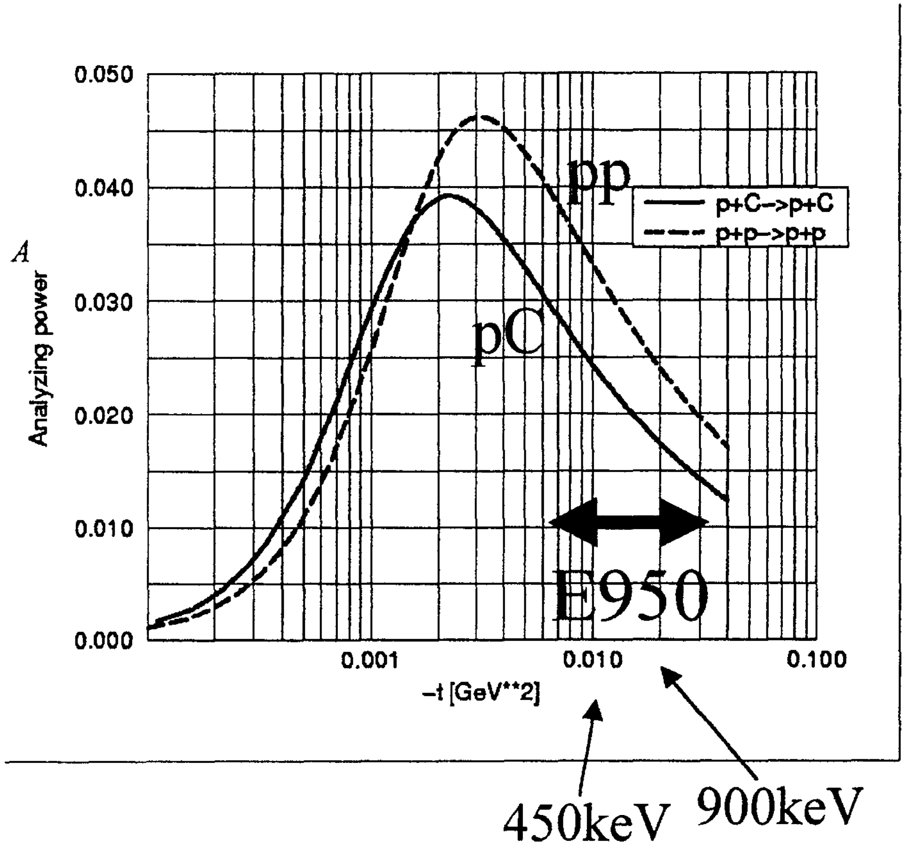
A New Polarimeter for RHIC

Kazuyoshi Kurita

Beauty of CNI

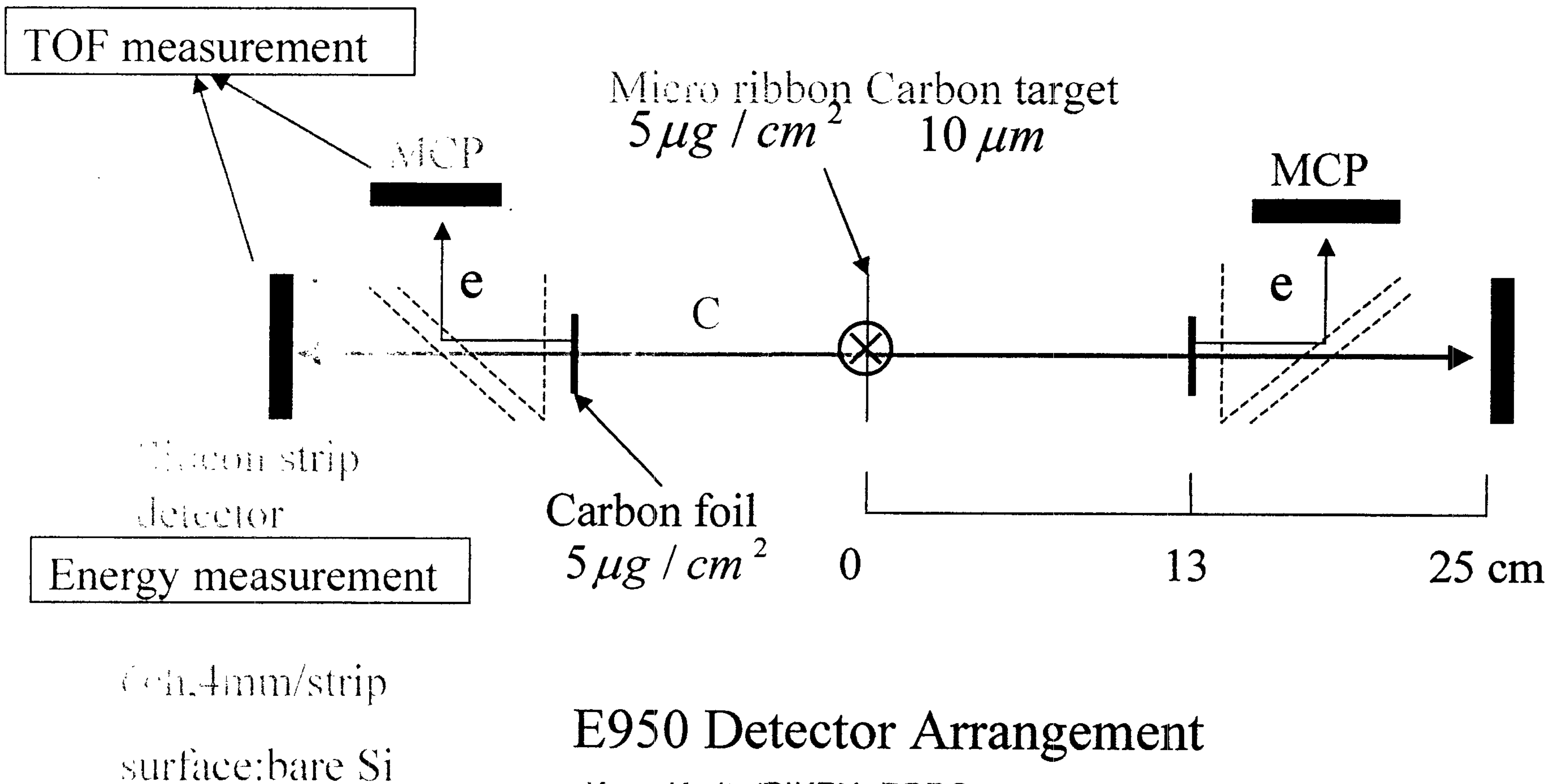
Asymmetry calculable

Weak beam momentum dependence



Kazu Kurita/RIKEN, RBRC

Experimental Design



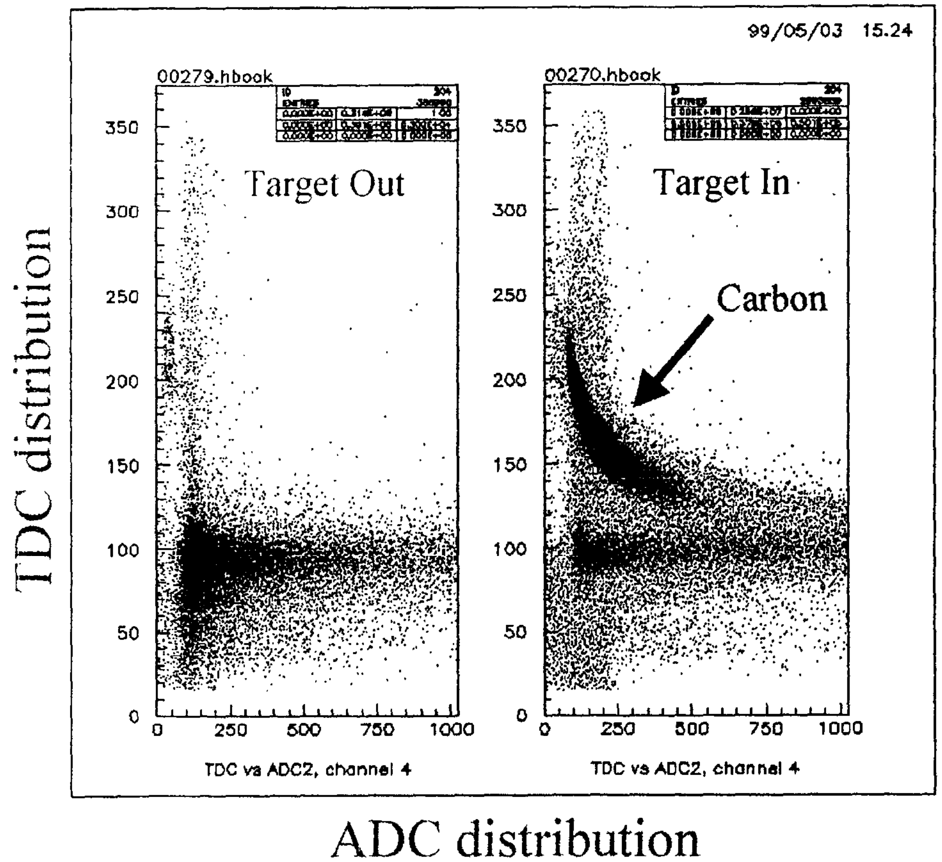
E950 Detector Arrangement

Kazu Kurita/RIKEN, RBRC

Si data

Comparison between target in/out runs gives the proof of Carbon detection

target frame is in the beam even with the target out run



Kazu Kurita/RIKEN, RBRC

Asymmetry

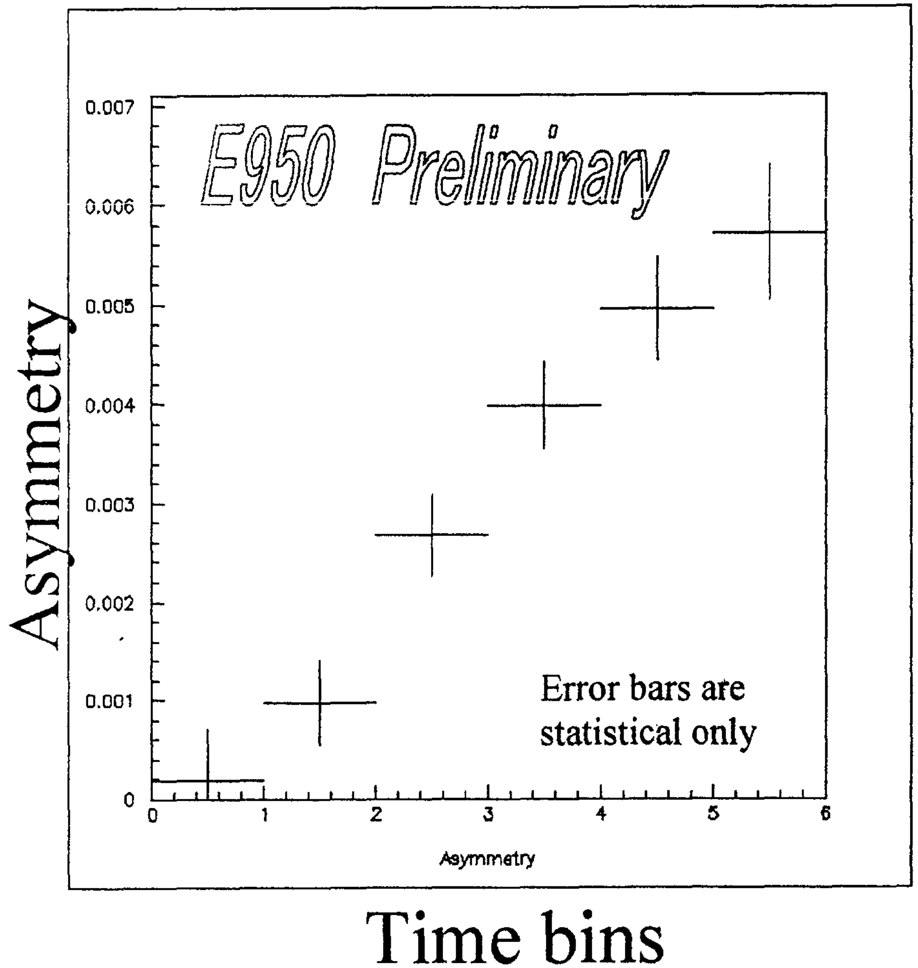
Carbon asymmetry is statistically significant

The physics asymmetry increases with arrival time => consistent with theory

Effect of different discriminator threshold was found to be very small

Asymmetry of prompt is less than 0.001

Other systematic error study is being done



Summary

1, We successfully detected carbon recoils inside the AGS ring

2, We see asymmetry

3, t dependence seems to be qualitatively consistent with theory but we are not ready to compare with theory quantitatively

4, We started the preparation for RHIC pC CNI polarimeter

Kazu Kurita/RIKEN, RBRC

The New Computer Center for PHENIX in Japan

Yashushi Watanabe

R&D of the CC-J

CC-J :The new computer center for Phenix in Japan

Yasushi WATANABE
RIKEN / RIKEN BNL Research Center

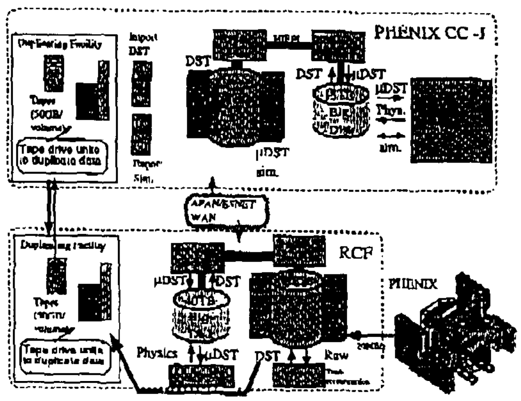
CC-J objectives

- Regional computer center for Japanese and Asian scientists
  - Serve for RHIC physics activities in Japanese and Asian scientists
- Major analysis center for Spin physics
- The Simulation Center for PHENIX
  - Major CPU resource for PHENIX
    - No CPU resource for simulation at BNL-RCF

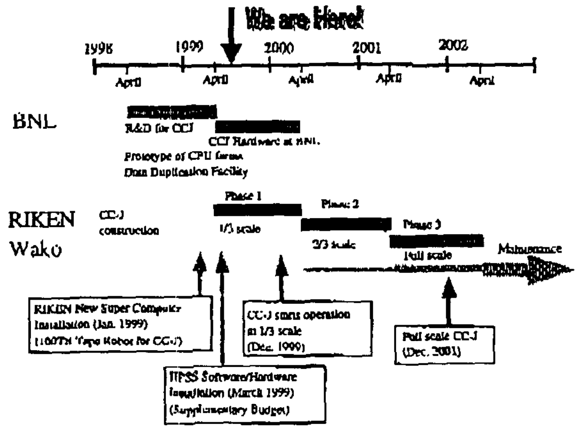
Requirements

- Huge experiment data to be analyzed
  - Data Summery Tape : ~150 TB / year !!
    - Huge storage capacity of data
    - Big pipe between storage and CPU
    - Data transfer method over the pacific
- Huge simulation needs
  - Correspond to huge experiment data
    - Huge CPU power
      - ~10k SPECint95 (= 500 PCs)
- Close couple with BNL-RCF

Principle Concept of the CC-J



Schedule



R&D Activity

- R&D for PC farm (at BNL)
    - Collaboration w/ RCF at BNL
  - Clustering tech. investigation for PC farm
    - File system investigation
      - For a huge number of PCs : NFS on LINUX
      - Between remote sites : AFS or Arla
    - Management method for a huge number of PCs
      - System management
      - Batch queuing system : LSF or PBS

» The farm will be transformed to "Real estate" for RBRC people

R&D Activity (cont'd)

- R&D for data transfer over the pacific
  - Data duplicating tech. (at BNL and Wako)
    - Transporting tapes by air is suitable for huge amount of data (~6 TB/week)
      - The first tape, NOW!
        - » Test of data transfer from Wako to BNL
    - Adding tape drive at BNL : still going on

» Dedicated tape drive for front end of the CC-J

Related Activities at Wako

- Have started to set up the "Real" CC-J at Wako
  - Tape robot is installed
  - HPSS is installed
  - Data server and PC farm (still small size) are installed
    - T. ICHIHARA (RIKEN/RBRC), Y. WATANABE (RIKEN/RBRC), Y. GOTO (RIKEN), N. HAYASHI (RIKEN), H. HAMAGAKI (CNS), S. SAWADA (KEK), S. YOKKAICHI (Kyoto Univ.)

Summary

- Fruitful R&D efforts
  - Clustering tech. investigation for PC farm
  - Near to success of data transfer over the pacific
- Have started to set up the "Real" CC-J at Wako
  - Tape robot and HPSS are installed
  - Data server and PC farm (still small size) are installed

Status and Future of RBRC-E

Masayasu Ishihara

Status and Future of RBRC-E

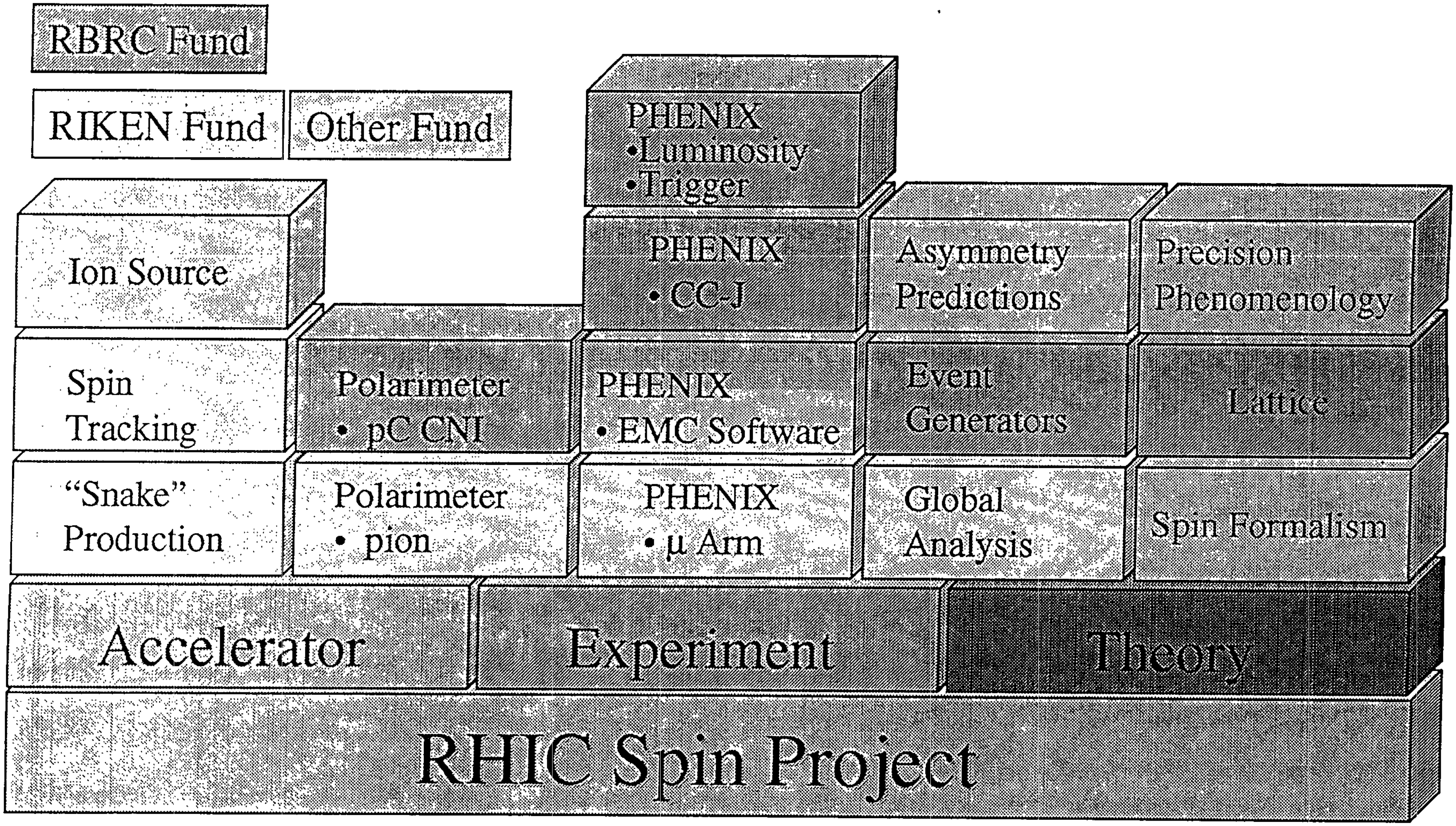
Masayasu Ishihara
RIKEN / RIKEN BNL Research Center

RBRC-E Objectives

Initial stage: Focus on RHIC Spin physics

- Explore RHIC Spin Physics in the area of
  - Experiment, and its intersections with
  - Theory, and with
  - Accelerator
- Enhance Spin physics activities in Japan
  - Involvement of Universities
  - (thus students)

RHIC Spin Project



RBRC-E Philosophy

- Leading Role in pursuing RHIC Spin Program
  - Be selective in choice of subjects
    - To take initiatives to enhance and accomplish the spin physics program
    - Currently, items crucial to start up the program
  - Be home of collaborative works
    - among experimentalists;

      a bridge between BNL & RIKEN

      a host of RSC
    - with theorists; RHIC Spin Collaboration Discussion,workshops
    - with accelerator physicists

"Round Table" a basis for all these collaboration

RBRC-E Philosophy cont'd

- Should have a close relationship with Japanese RHIC Spin physicists

Japanese Group (REG)

RIKEN and Collaborative Institutions

(~40 people, ~7 institutions)

† Enhance Spin (and RHIC) Physics Activities in Japan

- Need for Wako Base --> *"RIKEN Group for RSP"*
  - So far CC-J is main operational vehicle
- Involvement of Universities in Japan

† RBRC-E should keep close relation with *"RIKEN Group for RSP"*

RHIC Spin Physics

— Spin Physics Program (discussed at RSC mtg) —

- A_{LL} measurements at 200 GeV
  - to answer urgent question on ΔG
    - EMcal should be ready for $\pi 0$ and prompt γ
    - Muon Arm should be ready for J/ψ and Open charm, beauty and DY
    - P_B should be known to 10% precision
- A_{LL} and A_L measurements at 500 GeV
  - direct measurement of parity violation
    - Two Muon Arms should be ready for Z^0
    - P_B should be known to 5% precision
  - enhance kinematical coverage for ΔG
- A_{TT} and A_N measurements
  - transversity, QCD selection rule (switch off gluon effects)
  - higher twist effects

RBRC-E First-Year Activities

- Successful Launch of the group
  - collaborative efforts of BNL, RIKEN and RBRC
- Spin Specific Issues to be worked out
  - RHIC Polarimeter *(Kazu, Junji, Atsushi, Gerry, Yuji, Naohito, Ken)*
  - Luminosity Monitoring *(Gerry, MikeT, Hideto, Yuji, Naohito)*
  - Online Monitoring of Detector System *(Matthias, Hisayuki,Yuji)*
  - Offline Software (EMcal, μ Arm)*(Yuji, Sasha, Mao, Hiroki, Atsushi, Hisayuki, Naohito)*
  - Transverse Spin Effects *(Matthias and Daniel)*
  - Event Generator *(Naohito, Toshi-Aki and many)*
- Common facility for Spin (and RHIC) Physics
  - CC-J *(Takashi, Yasushi, Naoki, Hideto, Yuji, Naohito)*

RBRC-E Future

- Near Future
  - Offline Software (physics)
  - Triggering Rare Events
- Future Possibilities
  - Detector Upgrades e.g. VTX to clarify origin of J/ψ
  - High Precision Polarimetry
    - polarized gas jet target
  - Global Analysis of Parton Distribution Functions including Lattice Simulations

Urgent Needs for RBRC-E Organization

- 4 Fellows and 3 RAs
  - various expertise required
    - spin
    - collider
    - hardware
- "*RIKEN Group for RHIC Spin Physics*"
  - RIKEN staff and Visiting Scientists
  - Experiment and Theory

Summary

- Successful launch of the RBRC-E
  - thanks to BNL
- We will continue to explore spin physics with
  - RBRC theorists
  - BNL Group
  - "*RIKEN Group for RHIC Spin Physics*"

RBRC-E REPORT

RIKEN BNL Research Center
Brookhaven National Laboratory
Physics Department
Upton, NY11973-5000, USA

RIKEN BNL Research Center

Experimental Group

REPORT FOR THE PERIOD

October 1998 – March 1999

Masayasu Ishihara
Experiment Group Leader

1. Introduction

The Experimental Group of the RIKEN BNL Research Center was started on October 1, 1998 following a few months of preparatory activities. This report summarizes the activities for the first half-year period of the Experimental Group, including few of important preparatory activities.

The goal and scope of the Group

The Experimental Group will focus on RHIC physics through participation in RHIC experimental programs. In the initial stage we will particularly focus on RHIC Spin Physics Program in harmony with the strong institutional commitment of RIKEN to that program.

The Center is supposed to make a charming spring board of young physicists. The Experimental Group should as well develop to be a useful interface for collaboration between BNL and RIKEN experimental scientists.

The RHIC Spin Physics Collaboration desperately demands those core groups which could bring in consistent initiatives and enthusiasm in pursuing and enhancing the program. Therefore we look for hopefully creating such a group by trying to identify and select our subjects from uncultivated areas of physics and methodology. Along this line our current activities are directed to three subjects; 1) detector upgrade (e.g., R & D of polarimeter), 2) cultivation of physics analysis tools (such as event generator) and 3) R & D of Computer Center Japan (CC-J). Establishment of CC-J is a major project supported by the Center. CC-J will be a regional data analysis center for PHENIX to be placed at RIKEN, Wako).

The Group also makes efforts to take a triggering role in effectively enhancing the entire collaboration of spin physics. In this context the Center has hosted the 1998 annual meeting of RHIC Spin Physics Collaboration. We have also been trying to take a leading role in the PHENIX Working Group on spin physics.

Structure and operation:

The Group consists of senior staffs of visiting scientists and employed young physicists of Fellow(s) and Research Associate(s).

In materializing the BNL-RIKEN collaboration the senior staffs of the Group are largely invited from the both institutes. There is also strong participation by a Japanese group of senior scientists who collaborate with RIKEN scientists in the framework of PHENIX Spin Physics Collaboration-Japan or RIKEN Experimental Group.

As for employed young physicists we presently carry one Fellow and one Research Associate. These people have been selected and achieved through the standard procedure of the Center. Namely, the announcement of new research positions was made in *Physics Today* and the *CERN Courier*. The Scientific Advisory Committee for Experiment was established whose members consist of C. Prescott, R. Jaffe, J. Sandweiss, A. Masaike and S. Nagamiya. A total of 25 application was received. Advisory Committee members read the applications carefully and followed up with phone inquiries when further information was needed. Special seminars were also arranged so that personal interviews could be held. The Experimental Group has also established Program Advisor Group to enhance our scientific program by their advice. Thus the current organization reads;

Group Leader	Masayasu Ishihara (RIKEN)
Deputy Group Leader	Gerry Bunce (BNL)
Fellow	Matthius. Grosse-Perdekamp
Research Associate	Alexander Bazilevsky
Visiting Scientists (full time)	Takashi Ichihara (RIKEN)
	Yasushi Watanabe (RIKEN)
	Naohito Saito (RIKEN)
	Kazuyoshi Kurita (RIKEN)
Visiting Scientists (part time)	Kenichi Imai (Kyoto Univ.)
	Hideto Enyo (Kyoto Univ.)
	Toshi-Aki Shibata (Tokyo Inst. Tech.)
Program Advisors Group	Thomas Roser (BNL)

Michael Tannenbaum (BNL)
Yousef Makdisi (BNL)
Robert Jaffe (MIT)

2. Physics Discussions

a) Spin Discussion

We hold a weekly meeting on spin physics every Tuesday. The meeting is called "Spin Discussion". The meeting has been initiated by Gerry Bunce and Robert.L. Jaffe, and Naohito Saito joined the organizers. Now the organizing role has been transferred to younger generation, Naohito Saito and Werner Vogelsang. The web page is maintained by Yuji Goto since its start. Topics discussed in the meeting are summarized in Appendix 1.

b) Round Table Meeting

Round Table is the body to discuss the research direction of spin experimental group. We meet weekly to discuss various academic issues such as research activities of each personnel as well as organizational issues. The meeting is regularly attended by members of the Program Advisor Group.

3. Physics Research Activities

There is a large overlap in the members with RIKEN Experimental Group. Therefore, the research activities are largely attended by both RIKEN and RBRC groups:

a) R&D for computing center in Japan

We have designed the computing center in Japan for PHENIX data analysis in close relation with RHIC Computing Facility group. Takashi Ichihara and Yasushi Watanabe have led this project. The design has been reviewed by the RCF advisory committee in last December. The scope and technical choices are evaluated to be appropriate in the review report. A prototype machine has been successfully completed. Details can be found in Appendix-2. In fact, the prototype machine will be used ofr analysis at BNL and was recently used very successfully in an important simulation and its analysis efforts of the PHENIX experiment called Mock Data Challenge 2.

b) proton Carbon CNI polarimeter

The polarimeter for the RHIC as a polarized collider represents one of the major areas which require research and development in the RHIC spin project. Among various ideas, the polarimeter with the proton Carbon elastic scattering in Coulomb-nuclear-interference region has evolved as the best possibility. A test run as an AGS experiment E950. The experiment is being lead by Ken Imai and Kazu Kurita as well as University of New Mexico, and BNL. The detector system has been designed and constructed largely by this group. The system is now under final test using polarized proton beams in the AGS.

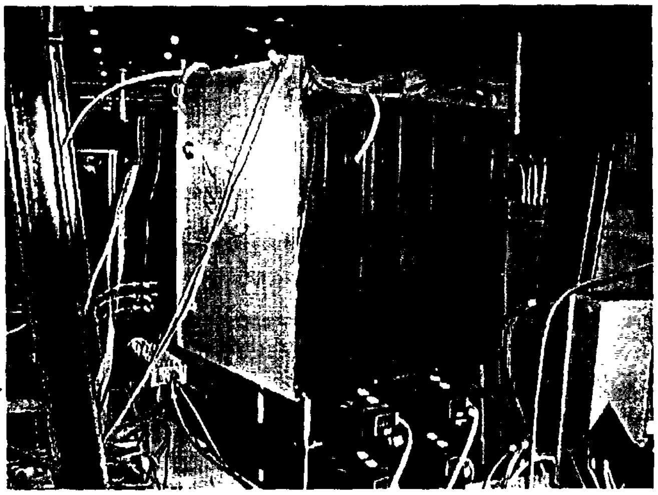
c) Spin physics analysis

In every PHENIX core week (monthly), we are holding a meeting of spin physics working group (PWG). The convener of the group is Hideto En'yo and often co-chaired by Yuji Goto. The PWG specified the needs of the software development and working. One of the highlights of the activity was Mock Data Challenge for proton-proton collisions. The "Mock Data" has been generated and will be reconstructed on the prototype of the CC-J. We will soon obtain the results of the analysis to be reflected to further development of the analysis software.

d) EM calorimeter

Electromagnetic calorimeter is the one of the most important detectors for spin physics, since most of the spin physics studies require photon or lepton in the final states. The PHENIX EM calorimeter is originally designed for heavy ion physics whose primary interests are lower energy photon and leptons < 10 GeV. On the other hand, spin physics requires high resolution and good linearity up to 80 GeV. To evaluate the performance of PHENIX EM calorimeter at high energy, we brought a part of the detector to CERN last summer to be exposed to electron beam at 6-80.0 GeV. Preliminary results show an agreement with our expectation from detailed simulations. This project is led by Yuji Goto and Naohito Saito. Hisayuki Torii from Kyoto University has participated in the experiment and is analyzing the data.

Matthias Grosse-Perdekamp is leading the development of online monitor program for EM calorimeter. Alexander Bazilevsky has been working for PHENIX EM calorimeter especially in the area of offline analysis and simulation. Continuation of such efforts seems natural.



e) Trigger

Trigger is very important for spin physics especially because most of the reactions to be identified are rare processes. In addition, we need to accumulate luminosity for each bunch crossing separately so that we can calculate the asymmetry even with different polarization in different bunches. This scheme has been worked out by Gerry Bunce and Mike Tannenbaum. Construction of the needed electronics (a special trigger extension board) will be supported in JFY99 by the center. Since the trigger issues are spin physics specific issues, we will continue the effort basing on the studies done by Yuji Goto for EM calorimeter and Naohito Saito for muon identifier.

4. Workshops

We have been holding workshops
a) to identify the problems to be solved in spin physics
b) to discuss possible solutions, and
c) to converge ideas to come up with the concrete proposal of activities.

For example, we have discussed various ideas on the polarimeter at RHIC in the RBRC workshop on RHIC Spin Physics. Following the discussions, we held another workshop for Physics Polarimetry at RHIC to generate a proposal to use AGS to test the idea of proton Carbon CNI polarimeter. The experiment has been approved as E950 and it represents one of the major activities at RBRC-E.

Through previous meetings of RHIC Spin Collaboration, there have been some discrepancies in interpretations of experimental results by experimentalists and theorists. We have identified "event generator" as an important "bridge" of theory and experiment and formed a collaboration to develop a full-fledged event generator for RHIC spin physics. So far we have held two workshops.

1) RHIC Spin Physics

Date: April 27-29, 1998

Organizers: Gerry Bunce, Yousef Makdisi, Naohito Saito, Mike Tannenbaum, Larry Trueman, and Aki Yokosawa

The workshop was held following a series of RHIC Spin Collaboration meetings. The collaboration consists of theorists, accelerator physicists, and experimentalists. We have been discussing:

a) how to make the case for RHIC spin physics,
b) how to realize the RHIC spin experiments, and
c) how to interpret future experimental data from the RHIC spin experiments.

The topics discussed in the workshop cover discussions, we held at RHIC Spin collaboration, which include gluon, polarimetry, parity violation, transversity, and single transverse spin effects. The experiment one of provides a very important opportunity to exchange various ideas to explore spin physics at RHIC.

We are planning to have another in near future.

2) Physics of Polarimetry at RHIC

Date: August 4-7, 1998
Organizers: Ken'ichi Imai and Doug Fields

The polarized proton program at RHIC will enter the unexplored region of the study of pp collisions. To maximize the output of the program, the determination of absolute polarization of the proton beam is very important.

Among several methods proposed to measure polarization of the proton beam, the measurement using elastic scattering of polarized proton from a thin carbon target in the CNI region is one of the promising methods with a precision of ~10%. The method is to obtain the beam polarization by comparing the measured asymmetry to the theoretical calculation. In this workshop, we would like to understand the precision from both theoretical and experimental side.

Although the main topic of this mini-workshop was focused on the p-C CNI polarimeter, the large x pion polarimeter and other methods was also discussed.

The goals of the workshop were:

- to come up with concrete experimental methods to identify the reaction at the RHIC transfer energy and higher energies,
- to identify the size of uncertainty in the theoretical calculation.

As a result of the workshop, we have completed a proposal of this measurement at AGS and approved as E950.

3) Event Generator for RHIC Spin Physics I and II

Date: September 21-23, 1998 and March 15-19, 1999
Organizers: Naohito Saito and Andreas Schaefer

The RHIC Spin program will provide a wealth of data allowing to determine a large variety of double- and single-spin asymmetries for proton-proton collisions. The physics discussion was so far centered around relatively clean observables like e.g. direct photons as a tool to measure the polarized gluon distribution. While such measurements are in principle straightforward one needs very good understanding of all background processes to realize the maximum quantitative precision. Experience with e.g. the physics at HERA shows that such studies require the development of several conceptually different Monte-Carlo codes, as only the comparison of such independent event generators seems to allow for a realistic estimate of the systematic theoretical errors involved. Furthermore such codes are crucial to extract interesting physical quantities from theoretically less clean spin asymmetries. Once RHIC Spin data will be available the development of adequate models will probably evolve into an industry, which might also lead to substantial cross-fertilization with the development of adequate codes for the description of heavy-ion collisions at RHIC.

The development and improvement of the required Monte-Carlo codes will certainly become an ongoing process during the complete running-time of RHIC, as one will try to describe an ever larger number of processes with increasing precision. Our workshop aims at getting this process well under way based on first developments in this direction.

As a result of the first meeting, we have specified the area of the work as follows:

(1) Comparison of the polarized event generator and unpolarized event generator with asymmetry weights
(2) Comparison of event generator and next-to-leading order analytic calculations
(3) Implementation of new processes such as parity violation due to quark compositeness
(4) Implementation of new polarized parton distributions
(5) Polarization effects in fragmentation process
(6) Intrinsic transverse momentum and parton distributions

Studies are underway in these directions and we heard the report of the progress in most of the area in the second meeting. We expect to finalize the first phase of the activities in coming third workshop.

Appendix 1

Spin Discussion – List of Topics Discussed

1997 Discussion Topics

October 1	Parity Violation by Basim Kamal and Mike Tannenbaum
October 7	Transversity by Bob Jaffe
October 21	Single Spin Asymmetries – by Jianwei Qiu
October 28	Polarimetry – by Larry Trueman
November 4	Higher Order Corrections – by Basim Kamal
November 10	General Discussion
November 18	Inclusive A_N measurements that can be made at RHIC detectors - Videbaek, Qiu
December 9	General Discussion
December16	General Discussion

1998 Discussion Topics

January 13	Beyond Standard Model Sensitivity for RHIC by Mike Tannenbaum
January 20	RSC/Compass Comparison by Gerry Bunce
January 27	SMC Semi-Inclusive Measurement by Akio Ogawa
February 3	RHIC experiment acceptances by Akio Ogawa
February 3	AGS Polarimeter Experimental Results by Yousef Makdisi
February 10	Resummation by George Sterman
February 24	RSC Meeting Discussion by Naohito Saito
February 24	Gauge Dependence of Delta-G by Bob Jaffe
March 3	Lattice QCD by Shigemi Ohta
March 10	Resummation Continued by George Sterman
March 17	Delta-G from Direct Photons by Chris Allgower
March 24	Gluon Polarization Errors by Yuji Goto and Akio Ogawa
March 31	Gluon Polarization Errors by Akio Ogawa (STAR)
April 7	Machine Polarization Issues by Mike Syphers

April 14	Parity Violation at RHIC - Definition of Observables by Jean-Marc Virey
April 14	Gluon Polarization Errors by Yuji Goto (PHENIX)
April 21	Spin at PHOBOS by Mark Baker
May 5	General Discussion
May 12	Charmonium at PHENIX by Naoki Hayashi
May 12	CP Violation Searches at RHIC by Vladimir Rykov
May 19	W Detection and Measurements at D0 (and CDF) by Kathy Turner
May 26	Measurement of Gluon Polarization at PHENIX with Pi0 Production by Yuji Goto
June 2	Quarkonium and Spin by Dima Kharzeev
June 9	W Detection and Measurements at D0 Continued by Kathy Turner
June 16	Heidelberg Meeting on CNI and Polarimetry by Larry Trueman
June 30	A Recent Test of p-Carbon CNI Polarimetry at Kyoto by Hideto Enyo
June 30	Luminosity Normalization for RHIC Spin by Gerry Bunce
September 22	General Discussion
October 6	SPIN98 Conference at Protvino by Naohito Saito and Gerry Bunce
October 13	The p-Carbon CNI Polarimeter Tests and Plans by Yousef Makdisi
October 20	Orbital Angular Momentum in the Proton and Parton Distributions by Sergei Bashinsky
October 27	General Discussion (Topics, Leaders, etc.)
November 3	DNP Meeting at Santa Fe and Symons Medium Energy Report by Gerry Bunce
November 20	The 1st Half-Day Meeting Orbital Angular Momentum and Off-Forward Parton Distributions by Xiandong Ji Transverse Spin and Transverse Momentum by Daniel Boer
November 24	Could CP- and T-Violation Be Tested in Polarized Proton Collisions at RHIC ? by Vladimir Rykov

1999 Discussion Topics

January 5	General Discussion (Topics, Leaders, etc.)
January 12	W Charge Asymmetry at the Tevatron by Kathy Turner

January 19	Luminosity Measurement by Sebastian White
January 26	Report of Hadron Collider Physics XIII in India by Naohito Saito
February 4	Determining the Gluon Contribution to the Proton's Spin with STAR by Les Bland
February 9	The 2nd Half-Day Meeting
	1) Spin-Flavor Structure of the Nucleon by Joel Moss
	2) CP-Odd Single and Double Spin Asymmetries in W/Z-Production by Polarized Hadrons and Leptons by Vladimir Rykov
February 16	Spin Asymmetries in Drell-Yan Production of Lepton Pairs by Werner Vogelsang
February 23	Why and How the Nucleon Spin Penetrates into the Glue and the Sea Quarks by Edward Shuryak
March 2	Determination of DeltaG in Compass by Matthias Perdekamp
March 9	Spin on Lattice by Thomas Blum
March 16	Transversity and Interference Fragmentation Functions by Bob Jaffe
March 18	Spin Measurements from HERMES by Naomi Makins
March 23	Spin on Lattice II by Shigemi Ohta

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Appendix 2

Progress Report on CC-J Project

February 1999

T. Ichihara, Y. Watanabe, H. Enyo, H. Hamagaki and M. Ishihara

Index

I) Review of the CC-J Proposal by RHIC Computing Advisory Committee

Following the suggestion by Prof. T.D.Lee on the Management Steering Committee meeting held in October 1998, the proposal of the CC-J has been submitted to the RHIC computing Advisory Committee to be evaluated on the scope, size, construction plan etc. The Advisory Committee meeting was held on 3rd-4th December 1998. Related documents are attached as follows.

-Ref. [1] Proposal for PHENIX Computing Center in Japan (CC-J)
http://spin.riken.bnl.gov/ccj/doc/plan/
-Ref. [2] Copy of the transparencies used for the presentation of the CC-J
http://spin.riken.bnl.gov/ccj/present/rev98dec/
-Ref. [3] Agenda for the RHIC-Computing Advisory Committee Meeting
-Ref. [4] RHIC-Computing Advisory Committee Meeting Report
http://spin.riken.bnl.gov/ccj/doc/plan/review/rev.ps
-Ref. [5] Action Plan and Response to the Review Report

Ref. [1] is the full report of the proposal of CC-J which was presented at the Advisory Committee. Ref. [2] is the copy of the transparencies used for the presentation of the CC-J proposal at the Advisory Committee meeting. Ref. [3] is the agenda for the meeting. Ref. [4] is the RHIC Computing Advisory Committee Meeting Report issued by the review committee. Ref. [5] is a brief summary of our response to the comments and recommendations of Ref. [4].

Presentation of the CC-J Proposal

The CC-J proposal was presented by three people 1) Prof. Bill Zajc, the spokesman of the PHENIN' who stressed the importance of the CC-J from the standpoint of the entire PHENIX collaboration, 2) Prof. Hideto En'yo from Kyoto Univ., an EC member of PHENIX representing the spin physics program explained the role and CC-J in terms of the entire PHENIX Japanese Collaboration, and finally 3) Dr. Takashi Ichihara from RIKEN and RBRC, the designated manager of planning and coordination office of CC-J who described the scope, requirements, system configuration of CC-J plan including the construction schedule of CC-J over the three years of period beginning in JFY 1999.

Review Report by the Committee

The review committee has issued a report entitled "RHIC-Computing Advisory Committee Meeting Report" (Ref 4]), in which their review summary on the CC-J proposal was included. This report involves following review items on the CC-J proposal: abstract, findings, comments and recommendations. As for the findings, the report has first appreciated **that this proposal has been endorsed strongly by the PHENIX collaboration.** It also points out several findings concerning such as place, transfer data rate per year, size, data duplication, construction plan and operation plans, with regards to the specifications of the proposal of Ref. [1]. As for the comments, it is first stated that **the purpose and scale of the facility appear to be appropriate for PHENIX**. Some technical comments concerning the tape bandwidth, HPSS operation staffing, data servers, data transfer method etc. are added. This report has also made the recommendations about the data import/export facility, the choice of tape drive & media, importance of the data duplication, staffing of the HPSS.

Action Plan and Response to the Review Report

1) Receiving the endorsement and encouragement of the review committee, we wish and plan to make the best effort to realize the CC-J at the size and scope of the proposed plan of Ref. [1].

2) As for the comments and recommendations, we have identified the problems and found that they are solvable rather easily with those measures as summarized in Ref. [5]

II) Progress report on R&D for CC-J

1) R&D for CC-J and Plan for the CC-J front-end station at RBRC

R&D for CC-J are planned to be completed for two years period beginning in JFY 1998. The purpose of this R&D is as follows: 1) to confirm the feasibility of the proposed scheme of CC-J by constructing the prototype and evaluating its performance. 2) to develop an appropriate system for data duplication at RCF. After the R&D that will be completed in 2000, These prototype systems will serve as the CC-J front-end station at the RCF.

2) Plan and Progress for JFY 1998

In JFY 1998, R&D for the following two items for construction are planned 1) prototype of the CPU farm 2) prototype of the data duplicating facility. As for the item 1), the prototype of the CC-J, which consists of 16 units of Pentium II CPU and a dedicated file server was completed in October 1999. The CPU farm is running well so far, and necessary software environments are almost established. The event-generation program PYTHIA is running successfully and MDC2 (second trial of Mock Date Challenge from the raw date to the physics analysis) will be performed in this prototype soon. For the item 2), extensive studies for the data duplication system have been carried out including the cost optimization. We are about to purchase a tape drive unit and its server computer for the further R&D works. This part of the system will be installed by March 1999 and the test of the data duplication and exportation will be followed. The schematic diagram for these prototype machines can be found in "R&D for CCJ" session in Ref. [2]

Appendix 3

Publication List

Papers

"RHIC Spin Physics"

N. Hayashi, Y. Goto, N. Saito, Proc. 6th Int. Workshop on Deep Inelastic Scattering and QCD (DIS98), GH. Coremans and R. Roosen (eds.) (World Scientific), Brussles (1998) 675--679.

"High-Energy Spin Physics at RHIC"(Japanese)

N. Saito, Genshikakku Kenkyu, Vol. 42, No. 4 (1998)
RIKEN-AF-NP-283, Jun 1998. 7pp.

"The PHENIX Experiment and PHENIX-J activities"

H. Hamagaki, N. Saito, Nucl. Phys. News 8 (1998) No. 4 26-30.

"Spin Physics with the PHENIX Detector System"

N. Saito et al, Nucl.Phys.A638575-578 (1998)
RIKEN-AF-NP-282, May 1998, e-Print Archive: hep-ex/9805003

"The PHENIX Experiment at RHIC"

D.P. Morrison et al, Nucl.Phys. A638 565-570 (1998)
BNL-65385, Apr 1998, e-Print Archive: hep-ex/9804004

"Measurement of Single Spin Asymmetry in Eta Meson Production in p(polarized)p and anti-p(polarized)p – Interactions in the Beam Fragmentation Region at 200 GeV/c"

FNAL-E704, D.L. Adams et al., Nucl. Phys. B510, 3-11 (1998)

"High-Energy Spin Physics and RIKEN BNL Research Center"(Japanese)

N. Saito, Parity (in Japan), Vol. 13, No. 12 (1998) 108-109.

Proc. RIKEN symposium on 'Quarks and Gluons in the Nucleon'
T.-A. Shibata and K. Yazaki (eds.),´ BNL-65234 (1997)

Proc. Workshop on Event Generator for RHIC Spin Physics,
N. Saito and A. Schaefer (eds.) BNL BNL-66116 (1998)

Proc. Winter School on 'Structure of Hadrons -Introduction to Hard QCD Processes'
N. Saito, T.-A. Shibata, K. Yazaki, (eds.)
Proc. of RIKEN BNL Research Center Workshop series Shimoda Japan (1998),

"QCD Selection Rules in Polarized Hadron Collisions"
R.L Jaffe and N. Saito Phys. Lett. B382, 165-172 (1996)

Oral presentation at the international symposiums and workshops

"Prompt Photon at PHENIX"
RBRC Workshop on RHIC Spin Physics
Y. Goto, BNL, Upton, New York, Apr. 1998

"Uncertainties in Delta-G Measurement at PHENIX"
RBRC Workshop on RHIC Spin Physics
Y. Goto, BNL, Upton, New York, Apr . 1998

"Gluon Polarization Measurement with Photon Detection at PHENIX"
13th International Symposium on High Energy Spin Physics
Y. Goto, IHEP, Protvino, Russia, Sep. 1998

"The Performance of PHENIX EM Calorimeter for Spin Physics"
APS Meeting, Division of Nuclear Physics
Y. Goto, Santa Fe, New Mexico, Oct . 1998

"Photons in Polarized pp Collisions at PHENIX"

Y. Goto, RBRC Workshop on Hard Parton Physics in High-Energy Nuclear Collisions
BNL, Upton, New York, Mar. 1999

"RHIC Spin Physics"

Naoki Hayashi, International Workshop on Deep Inelastic Scattering and QCD(DIS 98), Brussels, Belgium, Apr. 1998

"J/psi production in pp collision at PHENIX"

N. Hayashi, Y. Goto, K. Kurita, and N. Saito RHIC Spin Physics Workshop,
RIKEN BNL Research Center, USA, 27-29 Apr. 1998

"PHENIX Spin Physics"

Workshop on Event Generator for RHIC Spin Physics,
N. Hayashi´ RIKEN BNL Research Center, Sep. 1998

"RHIC Spin Program"

The Recent and Future Studies on the Nucleon Spin,
N. Hayashi, Nagoya, Univ., Japan, Nov. 1998

"RHIC Spin Program"

N. Hayashi, RIKEN Winter School, Shimoda, Japan. Dec . 1998

"Plan for the PHENIX Computing Center in Japan"

T. Ichihara, RHIC-Computing Advisory Committee Meeting, BNL, 3-4 Dec. 1998

"PHENIX computing Center in Japan"

T. Ichihara, RHIC Spin-J Physics Discussion, RIKEN Feb. 24th, 1999

"CNI Polarimeter for RHIC"

Ken'ichi Imai, RBRC Workshop on RHIC Spin Physics, BNL, Aug. 1998

"Proton-Carbon CNI Polarimeter with MCP"

K. Imai, RBRC Workshop on Physics on Polarimetry at RHIC, BNL, Aug. 1998

"Introduction to 1.5 day mini-workshop on Gluons at RHIC"

N. Saito, RIKEN BNL Research Center Workshop on RHIC Spin Physics, Apr. 1998.

"Measurement of Anti-quark Polarization at PHENIX"

N. Saito, RIKEN BNL Research Center Workshop on RHIC Spin Physics, Apr. 1998

"Introduction to Event Generator Workshop"

N. Saito, RIKEN BNL Research Center Workshop on Event Generator for RHIC Spin Physics, Sep. 1998

"Physics at RHIC - status of the heavy ion collider-"

N. Saito, Hadron Collider Physics XIII, TIFR, India, Jan 14-20, 1999

"RHIC Spin Physics - from structure to physics beyond standard model"

N. Saito, The 5th ICEPP Symposium, February 23, 1999

"Study of Spin-Flavor Structure of the Nucleon with PHENIX"

N. Saito, RIKEN BNL Research Center Workshop on "Hard Parton Physics in High-Energy Nuclear Collisions" March 1999.

"Introduction to Event Generator Workshop"

N. Saito, RIKEN BNL Research Center Workshop on Event Generator for RHIC Spin Physics II

"RHIC Spin Physics - from structure to physics beyond standard model"

N. Saito, IUCF Seminar, Indiana University, October 1998

"Simulation of J/Psi production in pp collision of PHENIX"

Sakuma et al, Fall Meeting of the Japanese Physical Society, Akita University, October 1998

"Construction of MuID panel for RHIC PHENIX"

H. Sato et al, Spring Meeting of the Japanese Physical Society, Toho University, Funabashi, Japan, March 1998

"Polarized Parton Distributions and Event Generator"

T.-A. Shibata, Event Generator Workshop, BNL, 1998

"Experimental Informations on the Inelastic Scattering"

T.-A. Shibata, RSC meeting on RHIC Spin Physics, BNL, 1998

"Quarkonium Productions",

T.-A.. Shibata, Event Generator Workshop, BNL, 1999

"RHIC-SPIN"

A. Taketani, RCNP Workshop for Spin Physics

RCNP, Osaka University, Osaka, Japan, August 1998

"Construction of MuID panel for RHIC PHENIX II"

E. Taniguchi et al, Fall Meeting of the Japanese Physical Society,

Akita University, Akita, Japan, October 1998

"Test experiment of CNI polarimetry with Kyoto Tandem accelerator"

J.Tojo, RBRC Workshop on Physics of Polarimetry at RHIC, BNL, Aug. 1998

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Oct. 1997 Special Postdoctoral Researcher, RIKEN
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RIKEN BNL Research Center
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Forthcoming RIKEN BNL Center Workshops

Title:	**OSCAR II: Predictions for RHIC**
Organizers:	Y. Pang/M. Gyulassy
Dates:	July 8–16, 1999
Title:	**Coulomb and Pion-Asymmetry Polarimetry and Hadronic Spin Dependence at RHIC Energies**
Organizer:	E. Leader
Date:	August 18, 1999

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RIKEN BNL RESEARCH CENTER

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MAY 27–28, 1999

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Nuclei as heavy as bulls
Through collision
Generate new states of matter.
T. D. Lee

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S. Sasaki
M. Wingate

Organizers: T.D. Lee and N.P. Samios